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A COMPARATIVE LITERATURE REVIEW OF THE ACADEMIC AND ENGLISH LANGUAGE EXPERIENCES OF INTERNATIONAL CHINESE PHD STUDENTS IN MALAYSIA AND OTHER COUNTRIES

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ABSTRACT

Studying abroad is a major form of internationalization in higher education, providing students with opportunities for academic, cultural, and personal growth through immersion in diverse learning environments. It is crucial to address problems concerning international Chinese PhD students and the English language needed for their academic experience while studying in Malaysia. It is also essential to address gaps in the literature on the limited research unearthing international Chinese PhD students' academic and English language experience in Malaysia. This paper presents a comparative literature review on the academic and English language experiences of international Chinese PhD students. The primary objective is to understand the situational development of international Chinese PhD students' academic and English language experiences in different contexts, which involves the unique features as well as complexities of international Chinese PhD students and their experiences in their doctoral academic journey.

Keywords:
International Chinese students, academic experiences, English language experiences.

INTRODUCTION

International Chinese student enrolment worldwide has been steadily increasing over the past few decades, driven by factors such as China's growing middle class, rising demand for higher education, and increasing global mobility among Chinese students. According to data from sources such as the UNESCO Institute for Statistics (UIS) and the Organisation for Economic Co-operation and Development (OECD), China has consistently been one of the largest source countries for international students. Chinese students are enrolled in various countries around the world, with popular destinations including the United States, the United Kingdom, Australia, Canada, and countries in Europe and Asia (OECD, 2021). The number of Chinese students going to the United States for postgraduate education reached 123,182 during the 2021-22 academic year, up by 3.64 percent from a year earlier. Meanwhile, the number of students going to the United Kingdom for postgraduate studies in the 2021-22 academic year was 88,755, up by 6 percent from a year earlier (China Daily, 2023).

Though the numbers at these traditional host countries seem to be increasing, it is not as much as it could be. The reason lies in the increasing xenophobia against Asian students including Chinese students and parochial nationalism which discourage Chinese students from developing their education and career in traditional host countries (Mok, 2021; Soria, 2021).

The enrolment of international Chinese students in Malaysian universities has been steadily increasing in recent years, driven by factors such as Malaysia's growing reputation as an educational hub, affordable tuition fees, and cultural proximity to China (Cheng & Liu, 2021). International Chinese students represent one of the largest cohorts of international students in Malaysian universities. From the data released by EMGS from 1st April to 30th June 2023, 12,665 applications were received. An interesting fact is that, among these applications, 4,700 are from China, accounting for the largest proportion of applicants and three times more than the second one, which is

Bangladesh. In addition, 2,920 and 2,895 applicants applied for Master's and PhD programmes, respectively, amounting to 42% of the total applicants (Shanshan & Abdul, 2024).

International Chinese PhD students prefer to pursue their studies at English Medium Instruction (EMI) institutions overseas. However, it is not always easy for international Chinese students to achieve their academic goals in EMI educational institutions (Sun & Soden, 2021; Sun et al., 2022; Xie & Lei, 2021; Clark & Yu, 2021). International Chinese students with Confucian-oriented educational backgrounds usually face hardships in their academic and English language experience in English medium institutions when they continue their higher education abroad (Sun & Soden, 2021; Sun et al., 2022).

The purpose of this paper is to explore current literature on the academic and English language experiences of students pursuing doctoral studies at international institutions.

RESEARCH METHODOLOGY

A comparative literature review methodology is adopted in this study as it involves systematically comparing and contrasting the findings, themes, or concepts from multiple studies on a similar topic or field. When exploring the academic and English language experiences of international Chinese PhD students, a comparative review can identify common academic challenges, language barriers, and coping mechanisms across countries like Malaysia, the United States, and the United Kingdom, while also highlighting the unique factors that shape these experiences in each region (Gough et al., 2021).

Various academic databases were used to search for literature, including Google Scholar, ResearchGate and Mendeley. Keywords and search terms included: "Chinese PhD students", "international students",” academic experiences”, "English language experiences", "Malaysia" "higher education", and "cross-cultural experiences." The inclusion criteria were peer-reviewed journal articles, dissertations, and conference papers; publications in English, studies focusing on Chinese PhD students abroad, and literature published within the last 10 years. Non-academic sources (e.g., news articles, blog posts), publications not in English, studies focusing on undergraduate or master's students, and literature older than 10 years were excluded. Databases included Google Scholar (29 papers), Scopus (6 papers), ResearchGate (12 papers), Web of Science (5 papers), Mendeley (10 papers).

Thematic analysis was used to identify, analyse, and report patterns (themes) within the data. There were two main steps. First, the researchers familiarised themselves with the contents and generated initial codes systematically across the entire data set. Second, the researchers defined themes and selected vivid, compelling extracts leading to a final analysis of selected extracts.

ACADEMIC EXPERIENCES OF INTERNATIONAL CHINESE STUDENTS IN MALAYSIA

Academic expectations at Malaysian universities encompass a set of standards, goals, and requirements that outline the academic performance and conduct expected from students enrolled in various programs. In addition, students are expected to uphold academic integrity by avoiding plagiarism, cheating, and other forms of academic dishonesty. Malaysian universities often emphasise the importance of conducting high-quality research and scholarly work, especially for graduate students pursuing advanced degrees (Tan & Wong, 2023). Universities expect students to demonstrate critical thinking, analytical reasoning, and problem-solving skills through their academic coursework and research activities. Additionally, students are expected to communicate effectively, both orally and in writing, in academic settings and professional contexts (Tan & Lim, 2022).

The academic experiences of international Chinese students are influenced by a multitude of factors, including cultural background, educational system differences, language proficiency, and institutional support (Zhang & Liu, 2022). Recent research suggests that international Chinese students in Malaysia may experience academic pressure due to the rigorous academic demands and expectations. This pressure can lead to stress, anxiety, and concerns about academic performance. Some international Chinese students may struggle with developing effective study skills, time management, and academic strategies necessary for success in the Malaysian academic environment (Wang & Tang, 2023). Additionally, adapting to the research-intensive nature of academic programs in Malaysia may pose challenges for international Chinese students, particularly in conducting independent research, reviewing literature, and analysing data (Shanshan & Abdul, 2024).

Jiang and Li (2021) note that differences in educational systems and expectations between China and Malaysia can pose additional hurdles for Chinese students, requiring them to adapt quickly to new academic norms and methodologies. Zhang and Liu (2023) discuss the difficulties in adapting to different academic cultures, including unfamiliar teaching methods, assessment styles, and expectations for class participation in Malaysian universities.

Cultural adaptation is another important factor influencing the academic experience of international Chinese PhD students. International Chinese PhD students in Malaysia face academic cultural differences during their academic journey (Bahack & Addi-Raccah, 2022). Chen and Liu (2021) discuss the challenges of cultural adjustment faced by Chinese students in Malaysian universities, including differences in teaching styles, communication norms, and social interactions. These cultural differences can impact students' confidence and engagement in academic settings, affecting their overall academic experience (Dong & Siti Maziha Mustapha, 2021).

The quality of advisory support and supervision provided to international PhD students significantly influences their academic progress and success. Effective supervision involves providing guidance, feedback, and resources to support students' research endeavours. However, some international Chinese PhD students in Malaysia have reported challenges related to mismatched expectations, communication gaps, and limited access to resources (Wang et al., 2022). These issues can hinder research productivity and delay academic milestones.

Balancing academic responsibilities with personal and family commitments can be challenging for international Chinese PhD students in Malaysia. The demanding nature of PhD studies, coupled with pressure to excel academically, may lead to burnout and mental health issues (Zhang & Yang, 2022). Students may struggle to maintain a healthy work-life balance, leading to decreased productivity and academic performance.

ACADEMIC EXPERIENCES OF INTERNATIONAL CHINESE STUDENTS: SIMILARITIES WITH OTHER COUNTRIES

Through academic experiences, international Chinese PhD students are similarly expected by both educational systems of Malaysia and other parts of the world to adhere to academic integrity by avoiding any form of academic dishonesty such as plagiarism or cheating in any tests; implement high-quality research and scholarly work; foster critical thinking abilities, analytical reasoning, and problem-solving skills; communicate effectively in English (Lou, 2024; Gao & Zhang, 2021; Xing et al.,2022).

International Chinese PhD students experience similar academic pressure in both Malaysian educational institutions and that of other parts of the world. Such pressure can cause stress and anxiety about the development of academic strategies and time management. International Chinese PhD students tend to be challenged when adapting to the research-intensive nature of academic programs in Malaysia and other parts of the world. They face the same difficulties in conducting independent research (Li, 2020; Lou, 2024; Wang, 2021).

Academic writing in English can also be a common problem for international Chinese PhD students in Malaysia and other parts of the world (Zhang & Watkins, 2021). International Chinese PhD students are usually challenged by institutional expectations of structuring research writing with proper citations of authorised sources (Wu & Hammond, 2022). These students also find it difficult to compare and contrast research findings in their own research.

ACADEMIC EXPERIENCES OF INTERNATIONAL CHINESE STUDENTS: DIFFERENCES WITH OTHER COUNTRIES

International Chinese PhD students have unique academic experiences that vary significantly depending on the host country. This section explores the differences between the academic experiences of Chinese PhD students in Malaysia and those in other countries, such as the United States, the United Kingdom, Australia, and European countries.

Malaysia's cultural and historical ties with China can result in a more familiar and comfortable academic environment for Chinese students. Malaysia's bilingual (Malay and English) environment can ease the language transition for Chinese students, especially those already proficient in English (Zhang, 2023). The presence of a significant Chinese-speaking community can reduce language barriers in everyday life and informal academic settings. This is not true for other traditional host countries such as the United Kingdom, Australia, the United States of America and other European countries (Cena et al., 2021). However, these countries provide academic cultures that expose Chinese students to various teaching and research methodologies. The academic environment in these countries can be highly competitive, with rigorous expectations and performance pressure because the universities are highly ranked globally and provide extensive research resources and funding opportunities (Wu & Hammond, 2022).

In terms of social integration and cultural adaptation, shared cultural practices, festivals, and cuisine in Malaysia can help Chinese students feel more at home, facilitating social integration during their academic journey (Zhao et al., 2023). Established Chinese communities and student associations can provide strong support networks (Rahman et al., 2021). In other countries, exposure to a wide range of non-Chinese cultures can enrich students' global perspectives but may also pose adaptation challenges. Students might experience cultural isolation or discrimination, affecting their social and academic life (Wang & Liu, 2023). A study revealed that Chinese students in Northern Ireland felt unwelcomed and unrecognized in the learning environment as a result of their inability to fully understand English in the nonbelonging culture (Cena et al., 2021).

The academic experiences of international Chinese PhD students vary significantly between Malaysia and other countries. While Malaysia offers cultural familiarity and targeted support, other countries provide diverse academic environments, rigorous academic standards, and extensive research opportunities. When international Chinese PhD students obtain their academic experiences, they also encounter diverse English language experiences depending on the host country.

ENGLISH LANGUAGE EXPERIENCE OF INTERNATIONAL CHINESE STUDENTS

The English language experience refers to the multifaceted encounters, interactions, and learning opportunities that students undergo as they engage with the English language in various contexts, including academic, professional, social, and cultural settings. This encompasses both formal and informal experiences that contribute to individuals' proficiency, fluency, and communicative competence in English (Ellis, 2021).

The English language experience of international students involves the process of acquiring English language skills, including listening, speaking, reading, and writing, through formal

instruction, immersion, self-study, and exposure to authentic language use. The experience also includes engaging in structured language learning activities, such as attending English language classes, workshops, and tutorials, which helps them develop language skills and improve their knowledge of grammar, vocabulary, and pronunciation (Ellis, 2021; Seng et al., 2023).

International students are also expected to utilize English language skills in real-life situations, such as participating in conversations, giving presentations, writing essays or reports, and engaging with English-language media (e.g., books, films, websites, social media) (Du & Faridah, 2024). In doing this, they gain exposure to diverse English language varieties, accents, and registers through interactions with speakers from different linguistic backgrounds, multicultural environments, and global communication platforms (Ellis, 2021; Seng et al., 2023).

In acquiring language skills, they need to overcome language barriers, difficulties, and challenges encountered during the language learning process, such as vocabulary acquisition, grammar rules, pronunciation, comprehension, and language anxiety. By integrating language learning with cultural understanding and awareness of English-speaking communities' customs, values, and norms, students would not only improve their language but also gain intercultural communication competence (Ellis, 2021; Seng et al., 2023).

ENGLISH LANGUAGE EXPERIENCE OF INTERNATIONAL CHINESE STUDENTS IN MALAYSIA

As Chinese language (Putonghua or Mandarin) is officially used as the language of instruction in the educational system in mainland China, mainland Chinese students tend to have hard times in Malaysian academic studies (Sung, 2022). Yeboah (2021) argued that international Chinese PhD students in Malaysia face many English language challenges caused by linguistic, psychological, and learning environment factors.

Linguistic factors include lack of vocabulary, pronunciation, insufficient knowledge of grammar rules, reading, and oral presentation (Burhanuddin & Indallah, 2021). Students with inadequate vocabulary are not able to convey their thoughts precisely. Their sentence organisation is weak which results in confusion, ambiguity, and misunderstandings (Thao & Trung, 2022). Their poor grammar leads to their incompetence in conveying the intended meaning or message clearly and effectively (Khasawneh, 2021). A qualitative study shows that international Chinese PhD students exhibit a low level of willingness to communicate in Malaysian academic environments (Ma et al., 2022).

Psychological factors, like anxiety, fear of mistakes, lack of confidence, hinder Chinese students from using English appropriately. Due to poor English language learning environment, limited learning resources, and low participation in English activities, Chinese students find it quite difficult to speak English eloquently. These learning environment factors are indicated by inadequate opportunities for Chinese students to speak English in and outside lessons, lack of a focus on language improvement in the curriculum, and an input-poor environment outside class. For Chinese students, they are not able to use English efficiently as they are not fully exposed to English language (Lee & Wong, 2023).

The English language experience of international Chinese students in Malaysia encompasses various aspects of language acquisition, learning, proficiency development, and cultural integration within the Malaysian academic and social context. This experience is shaped by a combination of formal language instruction, exposure to English in academic settings, social interactions with peers and faculty, and engagement with local culture (Huang & Chang, 2023).

International Chinese students in Malaysia engage in language acquisition and learning processes as they immerse themselves in an English-speaking environment. This includes attending English language classes, participating in language workshops, and using English in various academic

and social settings. Language learning strategies such as vocabulary acquisition, grammar practice, and language drills are commonly employed to enhance language proficiency (Wong & Tan, 2021).

Similarly, Chen and Tan (2021) found that international Chinese students actively engage in academic and social interactions in English within the Malaysian university context. Classroom discussions, group projects, and extracurricular activities provide opportunities for students to practise English, collaborate with peers, and build interpersonal relationships. These interactions contribute to language development and social integration.

The English language experience involves using English language skills in academic lectures, discussions, presentations, and written assignments. International Chinese students actively engage with English through coursework, research projects, and interactions with faculty and peers. Continuous exposure to English in diverse contexts contributes to the development of language proficiency and communicative competence (Chen & Lim, 2022).

International Chinese students in Malaysia encounter various challenges in their English language experience, including language barriers, cultural differences, and academic demands. Language learning strategies such as language immersion, language exchange programs, and peer tutoring are employed to overcome these challenges and enhance language skills (Huang & Chang, 2023). Additionally, students may seek support from language support services and participate in language enhancement activities offered by universities.

At the postgraduate level, international Chinese students in Malaysia often face challenges related to language proficiency, particularly in English, which is the primary language of instruction in many Malaysian universities (Li & Xie, 2021). Language barriers can impact their ability to comprehend lectures, engage in discussions, and produce written assignments, potentially affecting their academic performance.

The English language experience of international Chinese students in Malaysia is a dynamic and multifaceted journey characterized by language acquisition, learning, proficiency development, cultural integration, and academic and social interaction (Hor & Jusoh, 2021). Through engagement with English in various contexts, students enhance their language skills, adapt to cultural differences, and navigate the challenges of studying in a multicultural environment. Understanding and supporting the English language experience of international Chinese students is essential for promoting academic success, cultural exchange, and cross-cultural understanding in Malaysian universities.

ENGLISH LANGUAGE EXPERIENCE OF INTERNATIONAL CHINESE STUDENTS: SIMILARITIES WITH OTHER COUNTRIES

The English language experiences of international Chinese students share many commonalities across various countries, including Malaysia, as these students often face similar linguistic, academic, and social challenges in adapting to English-dominated academic environments.

In Malaysia, studies highlight that Chinese students struggle with both spoken and written English due to differences in linguistic structure and academic discourse expectations (Gao & Zhang, 2021). Similarly, in the United States and Australia, students report significant challenges in academic writing, understanding technical jargon, and coping with the fast pace of English-speaking classrooms (Wang & Brubaker, 2022). For example, a study by Liu (2023) showed that international Chinese students in the UK face difficulties in expressing critical thinking in English, a skill that is highly emphasised in Western academic settings.

In Malaysia, while there is a notable Chinese community and cultural similarities that ease some aspects of adaptation, the English language remains a critical hurdle. According to Tan (2022), international Chinese students in Malaysia face difficulties integrating into academic and social circles where English is predominantly spoken, despite Malaysia's multilingual environment. This finding is echoed in studies from the UK and Australia, where Chinese students often struggle with

feeling isolated due to language barriers that impede their participation in both academic and extracurricular activities (Wang, 2020). A global comparative study by Zhou et al. (2023) found that international Chinese students in countries such as Canada and Australia experience similar challenges in understanding local idiomatic expressions, humor, and informal conversational styles, all of which impact their social integration.

In Malaysia, universities often provide English language support programs specifically designed for international students, which include academic writing workshops and language courses (Lim & Lee, 2021). This mirrors practises in other countries such as the UK and Australia, where universities offer language support services tailored to help international students adjust to the demands of English-medium education (Evans & Morrison, 2022). According to Liu (2023), these support mechanisms are crucial in helping students build confidence in both academic and social settings.

A key coping strategy across different countries is the use of digital language-learning tools. In Malaysia, students frequently rely on mobile apps such as Duolingo and Grammarly to improve their grammar and vocabulary (Wang & Chen, 2021). In Australia and the USA, students use similar apps to supplement their learning and refine their academic writing (Liu, 2023). This reliance on technology highlights a global trend in how international Chinese students approach language learning.

The role of institutional support in helping international students navigate English language challenges is widely recognized in the literature. In Malaysia, universities have taken steps to provide tailored support services for non-native English speakers, such as English language workshops, one-on-one tutoring, and academic writing centres (Tan, 2022). These services are designed to improve students' language proficiency and reduce the stress associated with academic demands in a second language.

A study by Evans and Morrison (2022) on international students in Australia and the UK similarly highlights the importance of institutional support in bridging the language gap. In both regions, universities offer similar services, including preparatory English courses, tutoring, and peer mentoring programs, which help students acclimatize to the academic language expectations. Research suggests that these support mechanisms are critical to students' academic success and overall language improvement (Zhou et al., 2023).

ENGLISH LANGUAGE EXPERIENCE OF INTERNATIONAL CHINESE STUDENTS: DIFFERENCES WITH OTHER COUNTRIES

Malaysia is a multilingual country with English widely used in education, business, and government alongside Malay, which creates a more inclusive language environment for international Chinese PhD students. The significant Chinese-speaking population in Malaysia means that Mandarin and other Chinese dialects are commonly spoken, which can ease the transition for Chinese students but may also reduce the necessity for English proficiency in daily life (Hu & Zhang, 2024). Moreover, Malaysian universities may have moderate English language requirements for admission, with additional support programs available to help students meet language standards. While English proficiency tests like IELTS or TOEFL are required, the score thresholds may be slightly lower compared to institutions in English-speaking countries (Zhou et al., 2023).

In traditional host countries such as the United Kingdom, Australia, the United States of America, and other European countries, English is predominantly spoken. As such, students are required to have a higher level of English proficiency as it is the primary language for all academic and social interactions (Zhang & Gu, 2023). The necessity to use English in all aspects of life accelerates language acquisition but can be challenging initially for Chinese students with lower proficiency levels (Lim & Lee, 2021). Universities in English-speaking countries often have higher

IELTS or TOEFL score requirements for admission, reflecting the need for strong English proficiency for academic success.

The availability and structure of language support services also differ between Malaysia and other countries. In Malaysia, universities often provide tailored English language courses for international students, but these courses may be more limited compared to the extensive English for Academic Purposes (EAP) programs offered in countries such as the United States and the United Kingdom (Wang & Chen, 2021). For example, in the UK, universities often require international students to complete intensive EAP programs before starting their degree courses, whereas in Malaysia, such requirements are often more flexible or less comprehensive (Gao & Zhang, 2021).

Another key difference is the level of English language proficiency required for academic success. In Malaysia, the requirements for English proficiency may be more relaxed compared to Western countries. For instance, many Malaysian universities accept students with a lower International English Language Testing System (IELTS) score compared to universities in the UK, the US, or Australia (Tan, 2022). This leniency can make it easier for Chinese students to gain admission to Malaysian universities, but it may also mean that students face greater difficulties once they begin their academic programs, as they may not have developed the same level of academic English proficiency expected in more demanding English-speaking environments.

In contrast, universities in English-speaking countries typically have stricter entry requirements regarding language proficiency, requiring higher IELTS or Test of English as a Foreign Language (TOEFL) scores (Zhou et al., 2023). This ensures that students are better prepared for the rigors of academic writing and communication, but it also means that Chinese students face greater initial barriers to admission in these countries compared to Malaysia.

The relationship between language proficiency and social integration also varies. In Malaysia, the existence of a significant Chinese diaspora means that international Chinese students can often rely on Chinese as their social language, which may reduce the necessity of mastering English for social interaction. This situation contrasts sharply with countries like the US or Australia, where Chinese students must use English in nearly all social settings (Wang, 2020).

Research by Liu (2023) shows that Chinese students in English-speaking countries often report feeling socially isolated due to language barriers, as they struggle to engage in informal conversations, understand humor, and participate in extracurricular activities. In Malaysia, however, Chinese students may feel more comfortable integrating socially with the local Chinese community or other international students, but this can slow their overall English language development (Lim & Lee, 2021).

Moreover, the quality and accessibility of English language support can vary significantly in Malaysia due to differences between public and private institutions. Some private universities in Malaysia offer robust language support, while others may provide only minimal assistance. In contrast, in countries like Australia, institutional support for international students is often standardized and comprehensive, offering services like writing centers, English workshops, and peer support programs to ensure students meet the high academic language demands (Evans & Morrison, 2022).

The reliance on technological tools for language learning also presents notable differences. In Malaysia, Chinese students often use digital tools such as mobile apps (e.g., Duolingo, Grammarly) to supplement their English language learning (Wang & Chen, 2021). These tools are commonly used to compensate for the less intensive language immersion compared to countries like Australia or the US, where students are more likely to be fully immersed in English-speaking environments and may rely less on technology and more on face-to-face language practice (Zhou et al., 2023).

In English-speaking countries, while technological tools are also used, students are more likely to engage with native speakers and receive feedback in real time through classroom participation and interaction with peers. The use of technology in these countries often supplements

rather than replaces real-world language practice, which is more available in fully English-speaking environments (Evans & Morrison, 2022).

The English language experiences of international Chinese PhD students vary widely between Malaysia and other parts of the world. While Malaysia offers a bilingual and culturally familiar environment with moderate language requirements, other countries provide a more immersive and rigorous English language context. Understanding these differences can help institutions better support Chinese PhD students in developing their English language skills and succeeding academically.

THE INFLUENCE OF ENGLISH LANGUAGE EXPERIENCES ON ACADEMIC EXPERIENCES

In line with the growing reality English plays a major role in internationalisation of higher education, more and more higher education institutions have been incorporating the English language into their academic curriculum. The emergence of EMI across the educational sector is a dominant trend in internationalised higher education, which indicates the practical use of English in academic settings. Although there may not be any strict English language requirements at some institutions, the need to use and improve English for students to enrol in EMI programmes is obvious (Galloway & Rose, 2021). Moreover, the demand for Chinese PhD students to use English language in their research has been on the rise (Wu & Paltridge, 2021).

Language learning strategies have been found to improve academic achievement and language proficiency in foreign language learning. Research also stressed that effective learning strategies used by learners in foreign language learning is associated with better academic achievement (Seng et al., 2023). Zhang and Wang (2023) highlight that while many students possess basic English skills, they may struggle with academic English proficiency required for higher education. Common challenges include difficulties in academic reading, writing, speaking, and listening, as well as adapting to the nuances of English language usage in academic contexts (Chen & Li, 2022; Huang & Charanjit, 2024).

According to Zhan et al. (2021), proficient English writing skills are essential for Chinese PhD students, enabling them to effectively compose their dissertations and reports in English and share their research findings with the academic community. The English language experience significantly influences academic outcomes and employability prospects for international Chinese students. Wang and Chen (2023) found a positive correlation between English language proficiency and academic performance, highlighting the importance of language skills in achieving academic success. Furthermore, proficient English language skills are essential for accessing job opportunities and advancing career prospects in international contexts (Liu et al., 2021).

Chinese students studying abroad were found to meet academic obstacles due to their inadequate English language proficiency (Li & Zhang, 2022; Cheng & Liu, 2021). Jiang and Phusawisot (2023) discovered Chinese PhD students at a Thai university experiencing high level of English language difficulties (Jiang & Phusawisot, 2023). Zhao and Wang (2022) highlight language barriers as a significant hurdle, impacting students' ability to comprehend lectures, participate in discussions, and write academic papers in English.

To overcome these English-related academic challenges, several approaches are taken. Wang and Tan (2023) describe language enhancement programs designed to improve students' English proficiency through intensive language courses, workshops, and tutoring sessions. Additionally, Liang and Wong (2022) highlight the importance of mentorship and academic advising in guiding students through their doctoral studies and providing personalized support.

The English language experience is a significant aspect of international Chinese PhD students' academic journey in Malaysian universities. Wang and Liang (2023) emphasise that

proficiency in English is crucial for academic success in PhD programs, as students are required to engage with academic literature, communicate their research effectively, and participate in scholarly discussions. However, Huang and Chang (2022) found that language barriers can impede students' academic progress, particularly in writing and presenting their research, highlighting the need for targeted language support services.

CONCLUSION

The comparative review demonstrates that while international Chinese PhD students share similar struggles globally, the contextual factors of each host country—such as the linguistic environment, institutional support, and cultural integration—significantly influence their academic and English language experiences. Malaysia offers a unique case where the blend of linguistic flexibility and cultural proximity creates a more supportive academic environment compared to Western nations. Future research could explore how these contextual differences shape the long-term academic success and well-being of international Chinese students, as well as the effectiveness of various institutional interventions aimed at improving their experiences.

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PERFORMANCE OF INTERNAL CURING CONCRETE USING SAP AS AN INTERNAL CURING AGENT

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ABSTRACT
This study investigates the performance of internal curing concrete (C-S) incorporating superabsorbent polymers (SAP), compared to ordinary concrete (C). Standard specimens —150 mm cubes for compressive strength and 150 × 150 × 550 mm prisms for flexural strength— were tested in accordance with GB/T 50081-2019. The internal curing concrete (C-S) exhibited superior compressive strength, increasing by 6.1 N/mm² from 7 to 14 days and by 1.9 N/mm² from 14 to 28 days, compared to increases of 4.1 N/mm² and 2.3 N/mm² for the, respectively, for ordinary concrete (C). At 28 days, the flexural strength of internal curing concrete (C-S) exceeded that of ordinary concrete (C) by 0.6 N/mm² (17.6%). These improvements are attributed to the sustained moisture supply provided by the SAP, which promotes calcium silicate hydrate formation and reduces microcracks caused by autogenous shrinkage. Internal curing concrete shows potential for use in high-temperature or low-humidity environments, enhancing durability under challenging conditions. However, only one type of SAP was tested, limiting the generalizability of the findings. Future research should examine various SAP types and assess long-term durability. This study highlights SAP-based internal curing as a sustainable approach for producing high-performance concrete, contributing to advancements in civil engineering applications

Keywords:
internal curing concrete, superabsorbent polymer (SAP), compressive strength, flexural strength

INTRODUCTION

Concrete remains the most widely used construction material in modern infrastructure (Xie et al., 2021). Concrete structures have gained unparalleled prominence in the construction industry, becoming one of the primary choices for various construction projects. Effective curing is critical to achieving optimal mechanical properties and long-term durability in concrete structures by facilitating cement hydration, which forms strength-giving compounds like calcium silicate hydrate (C-S-H). Various curing methods exist, including water curing, steam curing, and internal curing, each influencing hydration kinetics and microstructure development differently (Bentz & Weiss, 2011).
The proposed research work on self-curing concrete offers several advantages compared to normal conventional concrete, such as enhanced early-stage strength, reduced shrinkage cracks, and a flowable mix without bleeding or segregation. Additionally, incorporating self-curing agents reduces the water content in the concrete, contributing to a healthier and more sustainable environment (Saravanakumar et al., 2023).

There are currently two prevailing categories of internal curing materials for concrete: inorganic porous materials and chemical polymers (Ma et al., 2015). Porous ceramics and superabsorbent polymers (SAPs) stand as exemplary representatives of inorganic porous and synthetic polymer internal curing materials, respectively.

The exceptional water retention capacity of SAPs has driven extensive research into their application for internal curing of concrete to mitigate early-age shrinkage (Mechtcherine, 2016). Numerous studies have investigated the influence of SAPs on the physical and mechanical properties of internally cured concrete (Zheng et al., 2021; Xie et al., 2020, 2021). The incorporation of SAPs

into cement pastes results in a marginal reduction in compressive strength after 28 days. However, in concrete mixtures, naturally occurring pores counteract the adverse effects of SAP-induced pores, leading to a notable improvement in compressive strength, particularly when using SAPs with a particle size of 400 μm (Niu et al., 2024).

The addition of preabsorbed water to SAPs delays the initial cement hydration process, accelerates the rate of later-stage hydration, and increases the ultimate degree of hydration, thereby enhancing the compressive strength of concrete. Moreover, pre-wetted SAPs significantly reduce concrete shrinkage, exhibiting a more pronounced shrinkage mitigation effect compared to the dry SAP addition (Huang et al., 2022). Larger SAP particle sizes have been shown to more effectively reduce autogenous shrinkage in early-age concrete (Lura et al., 2006), while SAP particles approximately 100 μm in size demonstrate superior water absorption efficiency (Jensen & Hansen, 2001, 2002). Additionally, SAPs enhance concrete durability under freeze-thaw cycles (Zheng et al., 2021).

The inclusion of SAPs also modifies the microstructural properties of concrete, increasing the density of the binding gel while introducing capillary pores. These alterations contribute to improved abrasion resistance and reduced chloride ion permeability (Kazemian & Shafei, 2024). However, existing studies have predominantly explored higher SAP dosages (0.2–0.5% by cement mass) and varying water-cement ratios in high-strength concrete, leaving a research gap concerning the performance of low-dosage (0.1%) pre-wetted SAPs in standard-cured, ordinary concrete.
Despite these advancements, challenges remain in the field of internal curing, particularly in determining the optimal dosage of internal curing agents and their compatibility with diverse concrete mix designs, which warrant further investigation (Kiran et al., 2025; Li & Kamaruzaman, 2025).

This study addresses this gap by investigating the performance of internal curing concrete (C-S) with 0.1% pre-wetted SAP (150 μm, 64.37 g/g absorption capacity) under standard curing conditions, in accordance with GB/T 50081-2019 (Chinese Standard, 2019). Unlike prior work, this research focuses on the low-dosage SAP's impact on compressive and flexural strength, offering insights into its practical applicability and sustainability benefits. Despite progress, further research is needed to optimize SAP particle sizes, dosages, and long-term durability across diverse concrete grades. This study contributes to the field by providing experimental data on low-dosage SAP's effects, advancing internal curing technology for sustainable, high-performance concrete applications in civil engineering.

EXPERIMENTAL PROGRAMS

Materials

The cement employed was of P·C42.5-grade composite Portland cement, boasting a density of 3180 kg/m³. The fine aggregate utilized was Zone II medium sand, characterized by a fineness modulus of 2.5 and an apparent density of 2670 kg/m³. For the coarse aggregate, continuously graded crushed stone within the size range of 5–25 mm was selected, sharing the same apparent density of 2670 kg/m³. The mixing water (W) was sourced from tap water. A polycarboxylate superplasticizer served as the water reducer, capable of achieving a water reduction rate of 28%.

The superabsorbent polymer (SAP) used in this study is a cross-linked acrylic acid/sodium acrylate copolymer with a particle size of 150 μm. Based on prior water absorption tests, the SAP exhibits a saturated water absorption capacity of 64.37 g/g, meaning it can absorb water equivalent to 64.37 times its own mass when fully saturated. For the dilution water experiments, 5 grams of SAP were weighed and saturated with water. The subsequent water release process was monitored, and the resulting water release curves are presented in Figure 1. The superabsorbent polymer (SAP) is incorporated into the concrete mixture in a pre-saturated state to ensure optimal water absorption. The SAP dosage is 0.1% of the cement mass. The choice of this low dosage aligns with prior research

indicating that SAP dosages of 0.1–0.2% by cement mass provide sufficient internal curing water to enhance cement hydration without introducing excessive free water, which could compromise early-age strength (Snoeck et al., 2020).

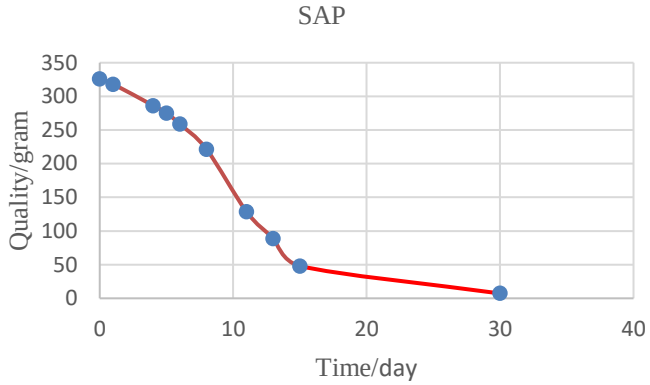

Figure 1: SAP water release process curve

According to the Chinese standard "Design Specification for Ordinary Concrete Mix Proportion" (JGJ55-2011) (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2011), the design strength grade of concrete was C35. The mix proportions for ordinary concrete (C) and internal curing concrete (C-S), with SAP as the internal curing agent, are presented in Table 1.

Table 1: Mix proportions of concrete kg/m^3

Sample No.	Cement	Sand	Stone	Water	Water reducing agent	SAP	Pre absorption water
C	359	809	1117	155	14.4	-	-
C-S	359	809	1117	155	14.4	0.359	23.1

DESCRIPTION OF MIX PROPORTIONS AND PREPARATION METHODS

Control Group Concrete (C)

The control group concrete, designated as "C," was formulated without superabsorbent polymer (SAP) to serve as a baseline for evaluating the performance of internal curing concrete. The mix proportion consisted of 359 kg/m³ of cement, 809 kg/m³ of sand, 1117 kg/m³ of coarse aggregate (stone), 155 kg/m³ of water, and 14.4 kg/m³ of water-reducing agent. These proportions were designed to produce a standard concrete grade suitable for assessing mechanical properties and hydration behaviour under conventional curing conditions.

The preparation of the control group concrete followed a standardized mixing procedure to ensure uniformity. Cement, sand, and coarse aggregate were dry-mixed in a laboratory mixer for 1 minute to achieve a homogeneous blend. Water and the water-reducing agent were then gradually added over 30 seconds while mixing continued. The mixture was mixed for an additional 2 minutes to ensure thorough dispersion and uniform consistency. The fresh concrete was cast into moulds, compacted using a vibrating table to eliminate air voids, and cured under standard conditions (20 ±

2 °C, 95% relative humidity) for 24 hours before demoulding. The specimens were subsequently cured according to the experimental protocol to evaluate compressive and flexural strengths.

Internal Curing Concrete (C-S)

The internal curing concrete, designated as "C-S," incorporated SAP to facilitate internal curing through controlled water release. The preparation of the internal curing concrete (C-S) differs from the control group concrete primarily in the incorporation of superabsorbent polymer (SAP) and its associated pre-absorption water. Specifically, 0.359 kg/m³ of SAP (a cross-linked acrylic acid/sodium acrylate copolymer with a particle size of 150 μm) and 23.1 kg/m³ of pre-absorption water were added to the mix to facilitate internal curing through controlled water release. Prior to mixing, the SAP was pre-saturated with the pre-absorption water in a separate container until fully absorbed, as determined by the SAP's saturated water absorption capacity of 64.37 g/g. During the mixing process, the pre-saturated SAP was added alongside the water and water-reducing agent over 30 seconds, while all other steps—dry mixing of cement, sand, and coarse aggregate for 1 minute, final mixing for 2 minutes, casting, compaction using a vibrating table, and curing under standard conditions (20 ± 2 °C, 95% relative humidity) for 24 hours before demoulding—remained identical to those for the control group concrete.

EXPERIMENTAL PROGRAMS

Testing method for compressive strength of concrete

Compressive strength tests were conducted on 150 mm × 150 mm × 150 mm cubic specimens in accordance with the Standard for Test Methods of Concrete Physical and Mechanical Properties (GB/T 50081-2019) (Ministry of Housing and Urban-Rural Development of the People's Republic of China & General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 2019). Each test group comprised three specimens. The loading rate was maintained between 0.5 MPa/s and 0.8 MPa/s during testing. The compressive strength of the concrete was determined using Equation (1).

$$f_{\mathrm{cc}} = \frac{F}{A} \tag{1}$$

where F is the failure load (N) of the specimen, A is the bearing area (mm²), and fcc is the compressive strength (N/mm²). The arithmetic mean of the compressive strength measurements from the three specimens was calculated to represent the compressive strength of the group, and reported to a precision of 0.1 N/mm².

Testing method for flexural strength of concrete

Flexural strength tests were conducted on standard prismatic specimens measuring 150 mm × 150 mm × 550 mm, in accordance with the Standard for Test Methods of Concrete Physical and Mechanical Properties (GB/T 50081-2019) (Ministry of Housing and Urban-Rural Development of the People's Republic of China & General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 2019). Each test group consisted of three specimens. During testing, the loading rate was maintained between 0.05 MPa/s and 0.08 MPa/s. The flexural strength of the concrete was calculated using Equation (2).

$$f_{\mathrm{f}} = \frac{Fl}{bh^2} \tag{2}$$

where F is the failure load (N) of the sample, l is the span between the supports (mm), b is the section width (mm), h is the section height of the sample, and ff is the flexural strength of the concrete

(N/mm²). The arithmetic mean of the flexural strength measurements from the three specimens was calculated to represent the flexural strength of the group, and reported to a precision of 0.1 N/mm². The loading schematic diagram of the experiments for ordinary concrete and internal curing concrete specimens is shown in Figure 2.

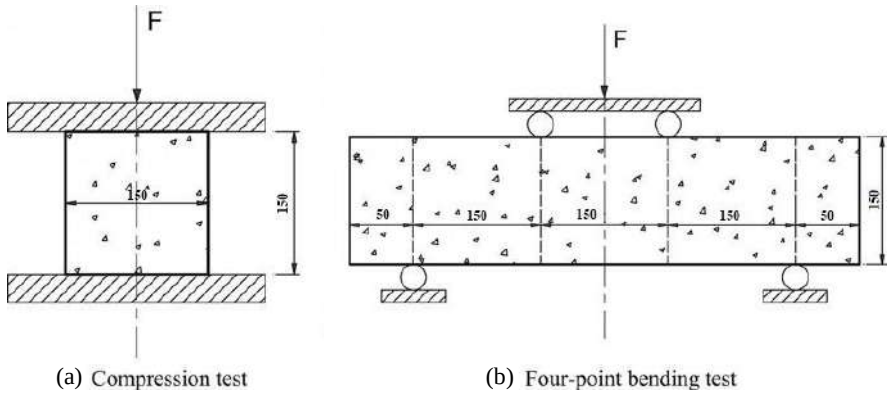

Figure 2: Loading schematic diagram of experiments

RESULTS AND ANALYSIS

Analysis of compressive strength of concrete

The compressive strength of the ordinary concrete (C) and the internal curing concrete (C-S) incorporating superabsorbent polymers (SAP) are is presented in Figure 3. For ordinary concrete, compressive strength increased by 4.1 N/mm² from day 7 to day 14, followed by a further rise of 2.3 N/mm² from day 14 to day 28, reflecting the typical pattern of strength development, where early gains are rapid but subsequently slow. In contrast, the internal curing concrete exhibited a more robust strength development, with an increase of 6.1 N/mm² from day 7 to day 14 and an additional 1.9 N/mm² from day 14 to day 28. This enhanced performance underscores the superior early and sustained strength growth of the internal curing concrete (C-S), attributed to the internal curing mechanism facilitated by SAP.

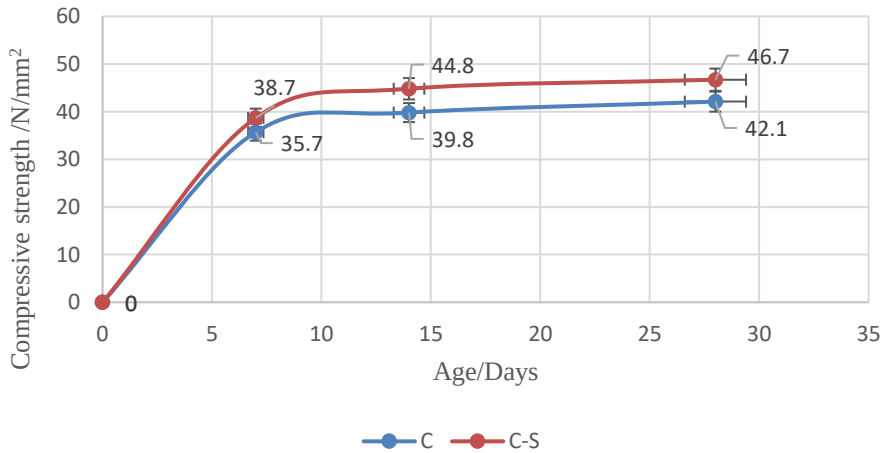

Figure 3: Concrete compressive strength under different ages

The improved compressive strength of the internal curing concrete (C-S) is primarily due to the SAP's ability to absorb and gradually release water during the hardening process, ensuring a sustained moisture supply for cement hydration. This prolonged hydration promotes the formation of additional calcium silicate hydrate (C-S-H) gel, the primary strength-contributing phase in cement paste, resulting in a denser and more uniform microstructure. Furthermore, SAP mitigates autogenous shrinkage by reducing internal stresses, thereby minimizing microcrack formation. This dual effect of enhanced hydration and reduced microcracking significantly enhances the compressive strength of the internal curing concrete (C-S) compared to the ordinary concrete (C) across all tested ages, highlighting the efficacy of SAP-based internal curing in improving concrete durability and performance in civil engineering applications.

Analysis of flexural strength of concrete

The flexural strength of the ordinary concrete(C) and the internal curing concrete (CS) are depicted in Figure 4.

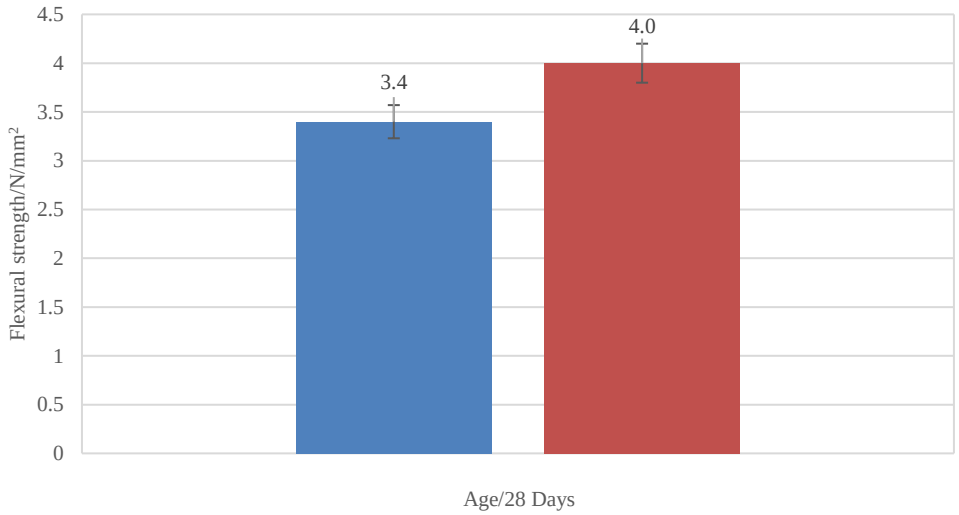

Figure 4: Flexural Strength of Concrete at the age of 28 days

At 28 days, the flexural strength of the internal curing concrete (C-S) exceeded that of ordinary concrete (C) by approximately 0.6 N/mm², representing an improvement of about 17.6%. This significant enhancement demonstrates the superior resistance of internal curing concrete to flexural stresses, attributed to the internal curing action of superabsorbent polymers (SAPs).

The enhanced flexural strength of the internal curing concrete (C-S) results from the SAPs' capacity to maintain a high internal relative humidity, facilitating more complete cement hydration. This leads to the formation of a robust cementitious matrix with increased calcium silicate hydrate (C-S-H) content, which enhances the concrete's tensile capacity. Additionally, SAPs reduce self-shrinkage by releasing stored water to counteract moisture loss, thereby limiting the development of microcracks caused by shrinkage stresses. This improved microstructural integrity not only bolsters the concrete's ability to withstand flexural loads but also enhances its overall durability. These findings validate the effectiveness of SAP-based internal curing strategies in optimizing the mechanical performance of concrete in civil engineering applications.

CONCLUSIONS

Section A: Demographic Information

This study investigated the performance of internal curing concrete (C-S) incorporating superabsorbent polymers (SAPs) compared to ordinary concrete (C), focusing on compressive and flexural strength development. The results demonstrate that SAP-based internal curing significantly enhances both compressive and flexural strengths. Specifically, the internal curing concrete (C-S) exhibited a more pronounced strength gain, with a 6.1 N/mm² increase from 7 to 14 days and 1.9 N/mm² from 14 to 28 days in compressive strength, compared to 4.1 N/mm² and 2.3 N/mm² for ordinary concrete. Similarly, at 28 days, the internal curing concrete (C-S) achieved a 17.6% higher flexural strength (approximately 0.6 N/mm² greater) than the ordinary concrete (C). These improvements are attributed to SAPs' ability to sustain cement hydration by releasing absorbed water, promoting the formation of additional calcium silicate hydrate (C-S-H) gel, and mitigating autogenous shrinkage to reduce microcrack formation, thereby enhancing microstructural integrity.

The findings have significant implications for civil engineering practice, particularly in optimizing concrete performance under challenging conditions. The sustained moisture supply provided by SAPs makes internal curing concrete particularly suitable for high-temperature or low-humidity environments, where conventional curing methods may be inadequate, such as in arid regions or in precast concrete production. By improving early and long-term strength, SAP-based internal curing can enhance the durability and service life of concrete structures, reduce maintenance costs and improve structural reliability.

However, this study has limitations. Only one type of SAP was tested, which may limit the generalizability of the results, as different SAP compositions or particle sizes could yield varying performance. Additionally, the study focused on mechanical properties at 7, 14, and 28 days, without exploring long-term behavior. Future research should investigate the durability of internal curing concrete, including resistance to freeze-thaw cycles, chemical attack, and long-term shrinkage behavior. Exploring different SAP types, dosages, and their impact on hydration kinetics and pore structure could further optimize internal curing strategies. Long-term studies on the performance of internal curing concrete under real-world environmental conditions are also recommended to validate its practical applicability.

This research underscores the potential of SAP-based internal curing to advance concrete technology, offering a sustainable solution for high-performance concrete in demanding construction scenarios. These findings contribute to the growing body of knowledge on internal curing and provide a foundation for developing innovative concrete mixtures tailored to specific engineering applications.

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A CONCEPTUAL PAPER ON THE EFFECT OF EMPLOYEE COMMITMENT ON EMPLOYEE WORK PERFORMANCE WITH ORGANISATIONAL IDENTITY AS THE MEDIATING FACTOR

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ABSTRACT

Employee commitment plays a critical role in driving work performance, significantly impacting organizational outcomes (Meyer & Allen, 1991). This concept paper intends to study the relationship between employee commitment and work performance with organisational identity as the mediator. Organizational identity reflects employees' alignment with their values and mission, shaping their self-concept and motivating their performance (Albert & Whetten, 2000). Work performance encompasses key metrics such as task efficiency, quality, teamwork, and organizational citizenship behaviors (Borman & Motowidlo, 1993). While much research exists on the link between employee commitment and performance (Meyer & Herscovitch, 2001), limited attention has been given to the role of organizational identity in this dynamic. This conceptual study addresses this gap by proposing a theoretical framework and hypotheses grounded in existing literature. The study highlights how organizations can harness employee commitment and organizational identity to achieve superior performance outcomes. Practical implications suggest fostering emotional attachment through policies that enhance affective commitment (Allen & Meyer, 1990) and reinforcing organizational identity through clear communication of values and culture (Ashforth & Mael, 1989). Hence, organizations can improve employee work performance by ensuring employees' goals and values are aligned with the organisation. Finally, the conceptual paper strives to contribute new knowledge by examining the relationship between employee commitment and work performance with organizational identity as the mediator.

Keywords:
Employee commitment, work performance, organizational identity, affective commitment, normative commitment, continuance commitment.

INTRODUCTION

Employee commitment significantly influences work performance by fostering motivation, engagement, and organizational loyalty. Committed employees tend to be more productive, display proactive work behavior, and align their actions with the strategic goals of the organization (Kumari & Afroz, 2021; Alrowwad et al., 2020). Organizational identity, defined as the degree to which employees perceive a shared sense of values, purpose, and vision with their organization, has recently emerged as a key psychological factor that can mediate this relationship (He & Brown, 2021; Sarwar et al., 2022). When employees strongly identify with their organization, their personal goals are more likely to align with organizational objectives, thereby enhancing their intrinsic motivation and performance outcomes (Zhu et al., 2020).

Despite the extensive literature on the direct relationship between employee commitment and work performance, the mediating role of organizational identity remains underexplored. Existing studies offer preliminary insights but lack a cohesive theoretical framework that integrates these constructs (Fatima & Bilal, 2022). Therefore, this conceptual paper aims to address this gap by proposing a framework that investigates the mediating influence of organizational identity on the commitment–performance relationship. The paper also explores the practical implications, strengths, and limitations of this framework, along with formulating relevant research hypotheses. Ultimately, this study seeks to contribute to a deeper understanding of how organizations can strategically

enhance employee commitment and identity alignment to achieve sustained performance improvements.

BACKGROUND

Employee performance remains a cornerstone of organizational success in today's fast-paced and competitive business environment. Employee commitment, which encompasses an individual's psychological attachment, emotional investment, and loyalty to their organization, has been consistently linked to enhanced job performance and organizational outcomes (Meyer & Allen, 1991; Meyer & Morin, 2016). Recent studies affirm that committed employees exhibit higher levels of motivation, proactive behavior, and alignment with organizational values, which translates into superior work performance (Alrowwad et al., 2020; Kumari & Afroz, 2021).

Organizational identity, defined as employees' shared understanding and internalization of an organization's values, mission, and vision, plays a pivotal role in shaping employee attitudes and behaviors (Albert & Whetten, 2000; He & Brown, 2021). When employees perceive a strong alignment between their personal identity and the organization's identity, they tend to develop a deeper sense of belonging and purpose, which enhances their engagement and productivity (Sarwar et al., 2022). This perception reinforces commitment and translates into improved individual and collective performance outcomes.

Although previous research has established the positive effects of employee commitment on work performance, the mediating role of organizational identity in this relationship remains underexplored. Emerging literature suggests that organizational identity may act as a psychological mechanism that channels the impact of commitment into productive behaviors and enhanced job performance (Zhu et al., 2020; Fatima & Bilal, 2022).

Therefore, this conceptual paper aims to address this gap by investigating how organizational identity mediates the relationship between employee commitment and work performance, offering deeper insights into organizational behavior and human resource development.

PROBLEM STATEMENT

Despite the extensive body of literature on employee commitment and work performance, there remains a critical gap in understanding how organizational identity mediates this relationship, particularly in today's fast-evolving work environment. The emergence of hybrid and remote work arrangements, shifting generational expectations, and an increased focus on personal meaning and psychological well-being have transformed how commitment and organizational identity function in contemporary workplaces.

Historically, employee commitment was closely tied to long-term loyalty and job security. However, in the modern context, commitment has become more individualized and value-driven. Employees—especially from younger generations such as millennials and Gen Z—now prioritize flexibility, purpose, and alignment with personal values over tenure or obligation. This shift calls into question the relevance of earlier commitment models, such as Meyer and Allen's (1991) three-component framework, which conceptualizes commitment as affective (emotional attachment), continuance (cost-based), and normative (sense of obligation).

Among these components, affective commitment has consistently shown the strongest and most positive relationship with work performance. Employees who are emotionally connected to their organization tend to display higher engagement, motivation, and willingness to contribute beyond formal job requirements (Meyer et al., 2002; Allen & Grisaffe, 2001). In contrast, continuance commitment, which is based on the perceived costs of leaving an organization, often results in

minimal discretionary effort. Employees may stay in their roles due to financial or career-related constraints, but not because they are genuinely engaged (Wu & Zhang, 2023). This form of commitment is frequently linked with stagnation, reduced innovation, and a compliance-based mindset, which limits its effectiveness in fostering high performance.

Similarly, normative commitment, rooted in a sense of obligation or duty, has shown mixed and often weaker associations with performance outcomes. While it may motivate employees to remain with an organization, this sense of obligation does not necessarily translate into proactive behaviors or enthusiasm for the job. In some cases, normative commitment may even generate feelings of guilt or emotional burden, which can negatively affect employee well-being and productivity (Somers & Birnbaum, 1998; Nguyen & Li, 2022). These findings suggest that both continuance and normative commitment lack the intrinsic motivational quality that affective commitment provides.

At the same time, organizational identity—the extent to which employees internalize and align with their organization's values, mission, and culture—has become increasingly crucial in shaping employee attitudes and behaviors. In modern workplaces, particularly those operating remotely or across diverse global teams, fostering a shared sense of identity has become more challenging. Studies by Gomes et al. (2022) and Rahman and Idris (2021) emphasize that organizational identity enhances job engagement and performance, especially when employees perceive a meaningful connection between their personal values and organizational goals. However, factors such as reduced in-person interaction, cultural misalignment, and weak leadership communication often dilute this connection, leading to disengagement and lower productivity (Epitropaki & Martin, 2005; Pratt, 1998).

Despite its significance, organizational identity is often overlooked as a mediating factor between commitment and performance. Moreover, it is frequently treated as a static construct rather than a dynamic and context-sensitive factor, shaped by ongoing communication, leadership behavior, and organizational culture.

Therefore, this conceptual paper seeks to address two key research gaps:

1. How does organizational identity mediate the relationship between employee commitment and work performance, particularly in modern work environments where traditional social bonds and identification cues are diminished?
2. Why is affective commitment more effective than continuance or normative commitment in predicting work performance, especially when aligned with a dynamic and well-communicated sense of organizational identity?

By addressing these questions, this study aims to modernize commitment theory, highlight the centrality of affective commitment, and propose a contemporary framework that integrates organizational identity as a mediating mechanism. The findings will offer theoretical and practical insights to help organizations enhance employee motivation, engagement, and ultimately, performance.

LITERATURE REVIEW

The literature review is focused on the study's key variables – employee commitment, organizational identity, and employee work performance – to establish the theoretical foundation and identify research gaps. Meyer and Allen's (1991) three-component model highlights the emotional, cost-based, and moral dimensions of commitment and their effects on work behaviors.

Organizational identity, reflecting employees' alignment with their organization's values and mission, is explored as a mediator linking employee commitment to work performance. Although organisational identity is critical, its effect as a mediator has not been deeply explored. Campbell (1990) proposed that employee work performance consists of two aspects which focus on organisational task completion and goals. This literature review explores the theoretical framework and hypotheses, forming the foundation for the study.

Recent scholarship has revisited the core constructs of commitment and identity in light of technological disruption and generational shifts. Huang and Singh (2024) emphasized that psychological identification with organizational goals enhances self-regulation and job engagement. Similarly, Gomes et al. (2022) found that remote employees with high organizational identity were more likely to exhibit proactive work behaviors, suggesting its importance as a mediating construct. Modern views on commitment extend beyond the three-component model. For example, Wu and Zhang (2023) examined emotional labor and showed that affective commitment was most predictive of contextual performance, especially in service industries. Conversely, continuance commitment showed a negative relationship with innovation and collaboration—emphasizing its outdated motivational value.

In the context of identity, Rahman and Idris (2021) found that a strong sense of organizational identity contributes to reduced employee cynicism and higher innovation, a critical mediator linking commitment to outcomes. Yet, despite these findings, no model integrates these newer insights into a comprehensive framework exploring mediation in depth.

EMPLOYEE COMMITMENT AND WORK PERFORMANCE

Work performance refers to the extent to which employees effectively fulfill their roles and contribute to the achievement of organizational goals. It is widely recognized as a multidimensional construct encompassing both task performance—the direct execution of job-specific duties—and contextual performance, which includes discretionary behaviors such as teamwork, cooperation, adaptability, and organizational citizenship behaviors (Koopmans et al., 2021; Campbell, 1990). High work performance is typically characterized by productivity, quality of output, problem-solving initiative, and proactive contributions beyond formal job requirements (Li, Ibrahim, & Mustapha, 2019). Given the growing complexity of organizational demands in a hybrid and digitalized work environment, understanding the psychological factors that influence performance is more relevant than ever (Huang & Singh, 2024).

One of the most influential predictors of work performance is employee commitment, particularly affective commitment, which refers to the emotional attachment an employee feels toward their organization (Meyer & Allen, 1991). Employees with high affective commitment tend to identify closely with organizational values and are more likely to exert extra effort, show loyalty, and engage in behaviors that enhance team and organizational outcomes. Recent studies reinforce this. Wu and Zhang (2023) found that affective commitment was a strong predictor of contextual performance in service roles, particularly those requiring emotional labor. Similarly, Nguyen and Li (2022) observed that millennial employees with higher affective commitment displayed greater engagement, adaptability, and resilience, all of which contributed positively to performance.

In contrast, continuance commitment—based on the perceived costs of leaving an organization—and normative commitment—a sense of obligation to remain—have been found to be less effective or even detrimental in predicting high performance. Continuance commitment often results in passive compliance, where employees remain with the organization due to necessity rather than genuine motivation, leading to minimal discretionary effort and lower innovation (Wu & Zhang, 2023). Normative commitment, while occasionally linked to organizational loyalty, can create internal conflict or emotional strain, particularly when it lacks alignment with personal goals or organizational culture (Nguyen & Li, 2022).

Meta-analytical findings continue to support the dominant role of affective commitment. For example, Riketta (2002) and Mathieu and Zajac (1990) highlighted a strong correlation between affective commitment and desirable organizational outcomes such as reduced turnover, enhanced job satisfaction, and higher performance. More recently, Gomes et al. (2022) emphasized that in remote and hybrid work environments, employees with stronger affective commitment maintained higher levels of initiative and job engagement, reinforcing its significance in modern contexts.

In summary, affective commitment remains the most robust and consistent predictor of employee work performance, as it is driven by emotional investment and value alignment rather than obligation or necessity. Organizations seeking to enhance performance should therefore focus on fostering affective commitment through practices that promote meaningful work, psychological safety, and shared purpose. These insights support the hypothesis that employee commitment—particularly its affective dimension—has a significant and positive impact on employee work performance.

ORGANISATIONAL IDENTITY AND EMPLOYEE WORK PERFORMANCE

Organizational identity refers to the shared perception among members of what the organization fundamentally represents—its core values, mission, and culture—which shapes both internal and external understandings of the organization's character (Albert & Whetten, 2000). When employees internalize these values, organizational identity becomes an integral part of their self-concept. This identification fosters behavioral alignment, as employees who strongly identify with their organization are more likely to act in ways that support collective goals, thereby enhancing motivation, engagement, and overall work performance (Ashforth & Mael, 1989; Rahman & Idris, 2021).

Recent studies continue to affirm this positive relationship. For instance, Gomes, Pereira, and Costa (2022) found that employees with strong organizational identity during remote work transitions demonstrated higher resilience, engagement, and initiative, particularly in settings where traditional workplace structures were disrupted. Similarly, Huang and Singh (2024) highlighted that organizational identity enhances self-regulation and clarity of purpose, which are critical to maintaining performance consistency in hybrid and fast-paced environments. In high-performing teams, a strong identity fosters psychological safety and collective ownership of success (Wu & Zhang, 2023).

Earlier foundational research remains relevant. Dutton, Dukerich, and Harquail (1994) demonstrated that employees who closely identify with their organization are more likely to perceive organizational achievements and challenges as personal, increasing their discretionary effort. Bartel (2001) found that such identity strengthens collaboration and problem-solving, while Carmeli, Gilat, and Waldman (2007) linked strong organizational identification to emotional engagement and improved workplace behavior. Riketta's (2005) meta-analysis further confirmed a positive correlation between organizational identification and outcomes such as job satisfaction and productivity. Likewise, Edwards and Peccei (2010) argued that organizational identity contributes to psychological fulfillment, which reinforces commitment and enhances performance.

However, the influence of organizational identity as a mediating factor is not without limitations. Over-identification may lead to emotional overinvestment, stress, and burnout, especially in high-pressure or crisis-prone environments (Pratt, 1998). Recent research echoes these concerns: Rahman and Idris (2021) noted that excessive alignment with organizational identity, in the absence of adaptive leadership, can suppress individual creativity and increase resistance to change. Additionally, the mediating effect of organizational identity is often context-sensitive. Epitropaki and Martin (2005) and Van Knippenberg (2000) pointed out that identity effectiveness can be weakened when there are misalignments in leadership style, culture, or communication, leading to confusion, detachment, or resistance. Abrams, Ando, and Hinkle (1998) further emphasized that fragmented or inconsistent leadership undermines shared identity, reducing its potential to positively influence performance.

In summary, while organizational identity is generally a positive force for enhancing work performance, its effectiveness as a mediating factor depends heavily on contextual factors such as leadership, communication, and organizational culture. When thoughtfully cultivated, organizational identity can align employee behaviors with strategic goals, thereby enhancing motivation, performance, and commitment in a sustainable manner.

EMPLOYEE COMMITMENT AND ORGANISATIONAL IDENTITY

The relationship between employee commitment and organizational identity plays a critical role in shaping workplace motivation, engagement, and performance—particularly when reinforced through effective internal communication (Huang & Singh, 2024). Strong employee commitment, especially affective commitment, enhances an employee's psychological connection to the organization, while organizational identity helps employees align their personal values with the broader mission of the organization. This dynamic relationship fosters a shared sense of purpose and deepens both emotional attachment and goal alignment.

Recent studies have reinforced the importance of this connection. Gomes et al. (2022) found that when organizational identity is clearly communicated and emotionally resonant, it significantly strengthens employee commitment, even in remote and hybrid work settings. Similarly, Wu and Zhang (2023) emphasized that organizational identity serves as a motivational anchor for committed employees, reinforcing collaborative behavior and role ownership. Effective communication of organizational values, vision, and culture enhances this connection, as noted by Smidts, Pruyn, and Van Riel (2001), who demonstrated that consistent messaging builds both identity and commitment simultaneously.

Earlier research also supports this interplay. Rousseau (1998) observed that employees with high affective commitment often internalize organizational goals, becoming more engaged and willing to exceed job expectations. Meyer and Herscovitch (2001) similarly argued that strong affective commitment enhances identification with the organization's values and long-term direction. Bartel (2001) found that employees involved in community outreach roles who identified strongly with their organization were more committed, collaborative, and proactive in problem-solving. Furthermore, Dutton, Dukerich, and Harquail (1994) highlighted that employees who perceive a clear alignment between their personal goals and the organization's purpose are more likely to sustain commitment and exert discretionary effort.

However, this relationship is not without complexity. The absence of effective communication or leadership support can weaken the commitment–identity link. Edwards and Peccei (2007) demonstrated that organizations lacking cohesive narratives or value communication may foster disengagement, leading to uncertainty about roles and decreased motivation. Epitropaki and Martin (2005) further warned that cultural and leadership misalignments could disrupt the commitment–identity relationship, making it harder for employees to find personal meaning in

organizational affiliation. Similarly, Van Dick (2001) cautioned against overemphasizing organizational identity at the expense of individual skills and team dynamics, as this may suppress creativity or undervalue personal strengths.

In summary, the interplay between employee commitment and organizational identity is a powerful driver of performance and engagement, particularly when supported by authentic and consistent communication of organizational values. However, this relationship must be carefully managed to avoid overidentification or neglect of other performance factors such as individual capabilities, team collaboration, and leadership support. Organizations that strike a balance between fostering emotional commitment and reinforcing shared identity are better positioned to cultivate high-performing and resilient workforces.

THEORETICAL FOUNDATION AND THE VARIABLES

This conceptual paper is grounded in two key theoretical frameworks: Social Identity Theory (Tajfel & Turner, 1979) and Meyer and Allen's (1991) Three-Component Model of Organizational Commitment. Together, these theories provide the foundation for understanding how employees' psychological connection to their organization influences their performance.

`The Social Identity Theory (SIT) posits that individuals derive part of their self-concept from the groups and organizations to which they belong (Tajfel & Turner, 1979). In an organizational context, organizational identity reflects how employees perceive, internalize, and align with the organization's values, mission, and culture. When employees identify strongly with their organization, they are more likely to feel a sense of belonging, adopt shared goals, and engage in behaviors that benefit the collective. Thus, SIT provides the theoretical basis for conceptualizing organizational identity as a mediating variable—it explains why employees' connection to organizational values may influence how their commitment translates into performance.

The Three-Component Model of Commitment developed by Meyer and Allen (1991) breaks down employee commitment into three dimensions: i.) Affective Commitment: An emotional attachment to, and involvement with, the organization. It is based on wanting to stay; ii.) Continuance Commitment: A calculative attachment based on the perceived costs of leaving. It is based on needing to stay; and iii.) Normative Commitment: A sense of obligation to remain with the organization. It is based on the feeling that one ought to stay.

These components capture the psychological bond between the employee and the organization and represent the independent variable in this study. Among the three, affective commitment is consistently found to be the strongest predictor of positive work outcomes, while continuance commitment is often linked to low intrinsic motivation, and normative commitment has mixed results, depending on cultural and contextual factors (Wu & Zhang, 2023; Nguyen & Li, 2022). This study focuses on three core variables: employee commitment, organizational identity, and employee work performance. Employee commitment serves as the independent variable and is examined through Meyer and Allen's (1991) three-component model, which includes affective, normative, and continuance commitment. Affective commitment, reflecting emotional attachment to the organization, is expected to have the strongest positive influence on performance. In contrast, continuance and normative commitment may exert weaker or more context-dependent effects. Organizational identity is positioned as the mediating variable, representing the extent to which employees internalize and align with their organization's values and mission. According to Social Identity Theory (Tajfel & Turner, 1979), such alignment enhances motivation, cohesion, and role clarity—particularly in dynamic or decentralized work environments (Gomes et al., 2022). Finally, employee work performance is the dependent variable, conceptualized as a multidimensional construct encompassing both task performance—the execution of core job responsibilities—and contextual performance, which includes discretionary behaviors such as teamwork, adaptability, and

organizational citizenship behaviors (Koopmans et al., 2021). This framework enables a comprehensive analysis of how different forms of commitment, mediated by identity, influence work outcomes.

By integrating the Social Identity Theory and the Three-Component Commitment Model, this conceptual framework seeks to explain not only whether employee commitment affects performance, but how and why that relationship occurs. Specifically, it proposes that organizational identity enhances the motivational quality of commitment, especially affective commitment, by aligning employee values with organizational goals. This theoretical alignment sets the foundation for the study's proposed hypotheses and the exploration of organizational identity as a dynamic, context-sensitive mediator.

THEORETICAL FRAMEWORK AND SUGGESTED HYPOTHESES

The conceptual framework is grounded in Social Identity Theory (Tajfel & Turner, 1979) and the Three-Component Model of Commitment (Meyer & Allen, 1991). The integration of these theories provides a more holistic view:

1. Employee Commitment (IV): Comprising affective, continuance, and normative components. This variable reflects the emotional and psychological bond employees have with their organization.
2. Organizational Identity (MV): Reflects the degree of identification with organizational goals, culture, and values, aligning with Social Identity Theory.
3. Employee Work Performance (DV): Includes task and contextual performance, reflecting both role fulfillment and discretionary contributions.

This alignment helps explain not only the "what" but also the "why" behind employee performance outcomes.

Therefore, the theoretical framework posits that employee commitment affects work performance directly and indirectly, with organizational identity as a mediating factor.

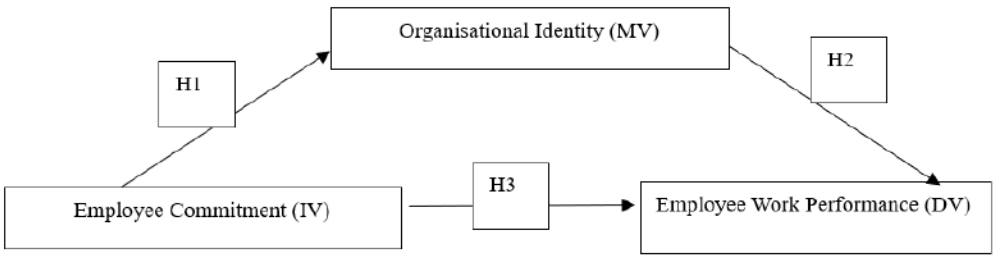

Figure 1: The Theoretical Framework

The theoretical research construct in Figure 1 illustrates the relationships between the independent variable (IV) (Employee Commitment), the mediating variable (MV) (Organizational Identity), and the dependent variable (DV) (Employee Work Performance).

SUGGESTED RESEARCH HYPOTHESES

H1: Employee commitment positively influences organizational identity.
H2: Organizational identity mediates the relationship between employee commitment and employee work performance.
H3: Employee commitment positively influences employee work performance.

MEASUREMENT OF VARIABLES

The following validated instruments are proposed to measure the key constructs in this study:
i.) Employee Commitment: Three-Component Commitment Scale (TCCS) by Meyer and Allen, as updated by Meyer et al. (2020) – Tables 1, 2 and 3.
ii.) Organizational Identity: Updated Organizational Identification Questionnaire (OIQ-2021), which integrates cultural alignment and psychological safety (Gomes et al., 2022) – Table 4
iii.) Work Performance: Individual Work Performance Questionnaire (IWPQ) developed by Koopmans et al. (2021), covering task and contextual performance – Table 5

Variable	Scale/Instrument	Sample items	Likert scale	Source
Employeee Commitment (IV)	Affective Commitment Scale (ACS)	1. I feel emotionally attached to this organization.	1 = Strongly Disagree, 5 = Strongly Agree	(Meyer, Stanley, & Parfyonova, 2020)
		2. I really feel as if this organization's problems are my own.	1 = Strongly Disagree, 5 = Strongly Agree	(Meyer, Stanley, & Parfyonova, 2020)
		3. I do not feel like "part of the family" at my organization (R).	1 = Strongly Disagree, 5 = Strongly Agree	(Meyer, Stanley, & Parfyonova, 2020)
		4. I feel a strong sense of belonging to my organization.	1 = Strongly Disagree, 5 = Strongly Agree	(Meyer, Stanley, & Parfyonova, 2020)
		5. This organization has a great deal of personal meaning for me.	1 = Strongly Disagree, 5 = Strongly Agree	(Meyer, Stanley, & Parfyonova, 2020)

Table 1: Employee Commitment (AC) (IV)

Table 2: Continuance Commitment (CC) (IV). Items marked with (R) are reverse-scored.

Variable	Scale/Instrument	Sample items	Likert scale	Source
Employeee Commitment (IV)	Continuance Commitment Scale (CCS):	1.) I am not afraid of what might happen if I quit my job without having another one lined up. (R)	1 = Strongly Disagree , 5 = Strongly Agree	(Meyer & Allen, 1991)
		2.) It would be very hard for me to leave my organization right now, even if I wanted to.	1 = Strongly Disagree , 5 = Strongly Agree	(Meyer & Allen, 1991)
		3.) Too much of my life would be disrupted if I decided I wanted to leave my organization now.	1 = Strongly Disagree , 5 = Strongly Agree	(Meyer & Allen, 1991)
		4.) It would not be too costly for me to leave my organization now. (R)	1 = Strongly Disagree , 5 = Strongly Agree	(Meyer & Allen, 1991)
		5.) Right now, staying with my organization is a matter of necessity as much as desire.	1 = Strongly Disagree , 5 = Strongly Agree	(Meyer & Allen, 1991)

Table 3: Normative Commitment (NC) (IV). Items marked with (R) are reverse-scored.

Variable	Scale/Instrument	Sample items	Likert scale	Source
Employeee Commitment (IV)	Normative Commitment Scale (NCS)	1) I feel like I am a part of this organisation.	1 = Strongly Disagree , 5 = Strongly Agree	(Meyer & Allen, 1991)
		2) I am quite proud to be able to tell people about the company.	1 = Strongly Disagree , 5 = Strongly Agree	(Meyer & Allen, 1991)
		3) The offer of a small salary adjustment with another company would not seriously encourage me to consider changing jobs.	1 = Strongly Disagree , 5 = Strongly Agree	(Meyer & Allen, 1991)
		4) Knowing that my work has contributed to the good of the organisation would please me	1 = Strongly Disagree , 5 = Strongly Agree	(Meyer & Allen, 1991)
		5)Leaving this company/organisation is a good decision. (R)	1 = Strongly Disagree , 5 = Strongly Agree	(Meyer & Allen, 1991)

Table 4: Organisational Identity (MV)

Variable	Scale/Instrument	Sample items	Likert scale	Source
Organizational Identity(MV)	Organizational Identification Questionnaire (OIQ-2021)	1. I feel strong ties with my organization's culture.	1 = Strongly Disagree, 5 = Strongly Agree	(Pereirac & Costa, R., 2022).
		2. When someone criticizes my organization, it feels like a personal insult.	1 = Strongly Disagree, 5 = Strongly Agree	(Pereirac & Costa, R., 2022).
		3. I am proud to tell others I work at this organization.	1 = Strongly Disagree, 5 = Strongly Agree	(Pereirac & Costa, R., 2022).
		4. I understand and support the organization's mission and vision.	1 = Strongly Disagree, 5 = Strongly Agree	(Pereirac & Costa, R., 2022).
		5. I feel that my values align with the organization's values.	1 = Strongly Disagree, 5 = Strongly Agree	(Pereirac & Costa, R., 2022).

Table 5: Work performance (DV)

Variable	Scale/Instrument	Sample items	Likert scale	Source
Work Performance	Individual Work Performance Questionnaire (IWPQ)	1. I effectively complete the tasks assigned to me.	1 = Strongly Disagree , 5 = Strongly Agree	(Koopmans et al., 2021)
		2. I actively help colleagues with their work when possible.	1 = Strongly Disagree , 5 = Strongly Agree	(Koopmans et al., 2021)
		3. I plan my work so it is done on time.	1 = Strongly Disagree , 5 = Strongly Agree	(Koopmans et al., 2021)
		4. I take initiative when something needs to be done.	1 = Strongly Disagree , 5 = Strongly Agree	(Koopmans et al., 2021)
		5. I keep myself focused despite distractions.	1 = Strongly Disagree , 5 = Strongly Agree	(Koopmans et al., 2021)

Employee Commitment is measured using the updated Three-Component Commitment Scale (TCCS) developed by Meyer et al. (2020), which captures the three core dimensions of commitment: affective, continuance, and normative.

a) Affective commitment (AC) reflects the emotional attachment and identification an employee has with the organization. It is widely recognized as the strongest predictor of positive work behaviors such as discretionary effort, loyalty, and intrinsic motivation.

b) Continuance commitment (CC) captures the perceived costs associated with leaving the organization. It reflects a more calculative form of attachment, often influenced by job security, career stability, and personal investment.

c) Normative commitment (NC) refers to a sense of moral obligation to remain with the organization, often stemming from cultural or social expectations.

Together, these three dimensions provide a comprehensive understanding of employee commitment, making the TCCS a suitable instrument for analyzing the different ways employees' psychological ties to the organization influence work performance—especially when mediated by organizational identity. Organizational Identity is assessed using the Organizational Identification Questionnaire (OIQ-2021), as updated by Gomes et al. (2022). This modern version expands on earlier models by incorporating key elements such as cultural alignment, shared values, and psychological safety. These dimensions allow researchers to capture how employees perceive their integration into the organization's mission and whether they see the organization's identity as part of their own. This aligns with the study's focus on organizational identity as a dynamic mediating variable in the commitment–performance relationship. Work Performance is measured using the Individual Work Performance Questionnaire (IWPQ) developed by Koopmans et al. (2021). This validated tool assesses both task performance (e.g., productivity, quality, and goal achievement) and contextual performance (e.g., teamwork, adaptability, and helping behavior), as well as counterproductive work behaviors. The IWPQ offers a broad and nuanced view of employee effectiveness, enabling the study to assess how various forms of commitment—when aligned with organizational identity—contribute to overall performance.

DISCUSSION

This paper offers a novel theoretical contribution by positioning organizational identity as a dynamic and context-sensitive mediator in the relationship between employee commitment and work performance. Departing from traditional models that often conceptualize organizational identity as a fixed or inherent trait, this study reconceptualizes identity as a fluid construct—shaped by factors such as leadership style, internal communication, and cultural alignment. This dynamic perspective reflects the evolving nature of modern organizations and the shifting expectations of today's workforce.

The uniqueness of this framework lies in its focus on affective commitment—the emotional attachment employees feel toward their organization—and its interaction with a well-developed sense of organizational identity. The model posits that when affective commitment is reinforced by strong organizational identification, it leads to enhanced task performance and contextual performance, such as collaboration, adaptability, and discretionary effort. This interplay has received limited attention in prior literature.

Moreover, the integration of contemporary constructs such as psychological safety and organizational agility provides a timely and relevant lens to examine performance outcomes. These elements acknowledge the importance of trust, adaptability, and emotional security in sustaining commitment and maximizing performance in today's rapidly changing work environments.

PRACTICAL IMPLICATIONS

Organizations can leverage these conceptual ideas to enhance employee commitment, such as implementing human resource policies and practices that foster affective, continuance, and normative commitment.

CONCLUSION

This concept paper highlights the importance of employee commitment and organizational identity in influencing work performance. Organizations can adopt the above concept ideas to devise human resources policies to improve work-life balance and ensure organizational success. It is recommended that future studies empirically test the proposed framework using qualitative methodologies (Zhang & Abd. Rahim, 2024) for further validation.

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AN INTEGRATIVE CONCEPTUAL FRAMEWORK OF WORK STRESS, JOB SATISFACTION, TRANSFORMATIONAL LEADERSHIP, AND TURNOVER INTENTIONS: A THEORETICAL PERSPECTIVE

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ABSTRACT

This study proposes an integrative conceptual framework of employee behavior by combining the Traditional Turnover Theory; the Stress, Appraisal and Coping Theory; and the Transformational Leadership Theory. The framework explores the relationships among work stress, job satisfaction, transformational leadership, and turnover intentions. Findings suggest that work stress negatively impacts job satisfaction, which in turn increases turnover intentions, while transformational leadership moderates this relationship by mitigating the adverse effects of low job satisfaction through emotional support, motivation, and individualized care. This study adopts an integrative literature review approach, systematically analyzing peer-reviewed journal articles published in the past three years (2022–2024) from Scopus, Web of Science, and Google Scholar. The selected literature was critically reviewed and synthesized to identify key theoretical insights and research gaps, forming the foundation for the proposed framework. The literature review highlights the limitations of single-theory frameworks and demonstrates the need for a comprehensive approach to understanding employee behavior. The proposed integrative conceptual framework emphasizes the dynamic interactions between stress and satisfaction and the crucial role of leadership in retaining employees. Practical implications for management include reducing work stress through workload redistribution, improving job satisfaction with career development opportunities, and adopting transformational leadership practices to foster employee commitment. Future research directions include longitudinal studies to track behavioral changes over time, cross-cultural research to test the framework's applicability in diverse settings, and the exploration of alternative leadership styles such as servant or transactional leadership. This integrative approach provides valuable insights for organizations aiming to reduce turnover and build a resilient, satisfied workforce.

Keywords:
Work stress, job satisfaction, turnover intentions, transformational leadership, employee behavior

INTRODUCTION

In the context of increasing globalization and intensifying competition, enterprises are confronted not only with external market challenges but also with the internal dilemma posed by employee turnover. Employee turnover behavior directly impacts operational efficiency, team cohesion, and long-term strategic development. As knowledge economies and information technology advance rapidly, employees have become one of the most valuable assets for organizations. Therefore, understanding and managing employee turnover intentions have become critical components of modern organizational management (Griffeth et al., 2000). Turnover leads to not only the direct loss of human capital but also a series of chain reactions, such as decreased team morale, damaged client relationships, and increased costs associated with recruitment and training (Antony et al., 2024; Jamal et al., 2024; T. Wang et al., 2023).

Numerous studies have explored the relationships among work stress, job satisfaction, and turnover intention (Hameli et al., 2024; Khan et al., 2024; Ribeiro et al., 2023; Soeprapto et al., 2024; Wu et al., 2023). These studies often adopt a single theoretical perspective, such as the Traditional Turnover Theory (Mobley, 1977) or the Stress, Appraisal and Coping Theory (Lazarus, 1984). The Traditional Turnover Theory posits that declining job satisfaction leads to increased turnover intentions. In contrast, the Stress, Appraisal and Coping Theory focuses on how employees perceive and manage work stress. However, as work environments become increasingly complex and employee needs more diverse, these single-theory frameworks exhibit limitations in practical application. They struggle to explain the dynamic relationships between work stress, satisfaction, and turnover intention, as well as how these factors interact under different organizational contexts (Hameli et al., 2024; Khan et al., 2024; Ribeiro et al., 2023; Soeprapto et al., 2024; Wu et al., 2023).

To address this gap, this study attempts to integrate the Traditional Turnover Theory, the Stress, Appraisal and Coping Theory and the Transformational Leadership Theory to develop a comprehensive employee behavior conceptual framework. This conceptual framework aims to elucidate how work stress influences turnover intentions through job satisfaction and to explore the moderating role of transformational leadership in this process. Transformational leaders, by offering motivation, support, and personalized consideration, can mitigate negative emotions caused by work stress, thereby reducing turnover intentions (Alanazi et al., 2023; Asbari, 2024; Ghorbani et al., 2023; Rojak et al., 2024). In summary, this conceptual framework integrates work stress, job satisfaction, transformational leadership, and turnover intentions to address theoretical limitations and offer a comprehensive perspective on the dynamic interplay among these factors.

This study's key innovation lies in its integration of multiple theoretical perspectives, resulting in a comprehensive integrative conceptual framework to explain the complex interplay among work stress, satisfaction, and turnover intentions (Khan et al., 2024; Pinnington et al., 2024; Rasheed et al., 2024). Furthermore, the study highlights the importance of transformational leadership in modern management practices, illustrating how it buffers the negative effects of reduced job satisfaction on turnover intentions (Wang et al., 2024; Yasin et al., 2023; Yuan et al., 2024). In addition to deepening theoretical understanding, this research offers actionable strategies for organizations to improve employee experience and reduce turnover rates (Griffeth et al., 2000; Tabak et al., 2024; Wang et al., 2024).

By applying this integrative conceptual framework, organizations can more accurately identify the underlying causes of employee turnover and adopt targeted management practices, such as optimizing work environments, providing psychological support, and fostering transformational leadership skills. These measures not only enhance employee satisfaction and retention but also provide organizations with a stable and sustainable foundation to adapt to evolving challenges in modern workplaces.

LITERATURE REVIEW

Traditional Turnover Theory

The Traditional Turnover Theory, introduced by Mobley (1977), posits that job dissatisfaction is a primary driver of turnover intentions. According to Mobley, turnover intention develops gradually as dissatisfaction accumulates over time. Factors contributing to dissatisfaction include the work environment, compensation, career development opportunities, and interpersonal relationships within the organization. When dissatisfaction reaches a critical threshold, employees are likely to consider leaving their jobs. Griffeth et al. (2000) further expanded this theory by emphasizing that organizational commitment—the psychological attachment an employee feels towards their organization—is another significant predictor of turnover behavior. Employees with higher

organizational commitment are less likely to develop turnover intentions, even if they experience temporary dissatisfaction.

While the Traditional Turnover Theory has significantly advanced our understanding of employee turnover, it has notable limitations. One key critique is that it assumes job satisfaction to be a static variable, remaining relatively constant over time (Galanis et al., 2024; Jamal et al., 2024; Tyagi et al., 2023; T. Wang et al., 2023). In reality, job satisfaction is highly dynamic and influenced by various situational and personal factors, such as changes in leadership, workload, and organizational culture. For example, employees who initially report high job satisfaction may experience a decline due to unexpected organizational changes, such as restructuring or policy shifts (Winfield & Paris, 2024; Yasin et al., 2023; Yin et al., 2023; Yuan et al., 2024).

Another limitation is the theory's linear and deterministic nature. It suggests a straightforward progression from dissatisfaction to turnover intention and finally to actual turnover. This oversimplified approach fails to capture the complex interplay of factors such as work stress, leadership style, and external job market conditions (Ribeiro et al., 2023; Saberi et al., 2023; Tabak et al., 2024; Wang et al., 2024). Empirical studies have shown that employees may remain in unsatisfactory jobs due to economic conditions, personal commitments, or lack of alternative opportunities (Antony et al., 2024; T. Wang et al., 2023). Conversely, satisfied employees might still leave if they perceive better career growth prospects elsewhere (Rasheed et al., 2024; Soeprapto et al., 2024).

Moreover, traditional turnover models largely neglect the influence of workplace stress and leadership dynamics. Research indicates that work stress can significantly impact turnover intentions, independent of job satisfaction levels (Jiang et al., 2023; Malik, 2023; Pepple et al., 2023; Winfield & Paris, 2024). Additionally, transformational leadership has been shown to mitigate turnover intentions by fostering a supportive and motivating work environment (Galanis et al., 2024; Yasin et al., 2023). Therefore, while the Traditional Turnover Theory provides a foundational framework, its applicability in modern, dynamic work environments remains limited.

Stress, Appraisal and Coping Theory

The Stress, Appraisal and Coping Theory, developed by Lazarus and Folkman (1984), focuses on how individuals perceive and respond to workplace stressors. The theory proposes a two-stage process: primary appraisal and secondary appraisal. In the primary appraisal stage, employees assess whether a stressor poses a threat to their well-being. In the secondary appraisal stage, they evaluate their resources and options for coping with the stressor. Coping strategies are typically categorized as problem-focused coping, which addresses the source of stress directly, and emotion-focused coping, which aims to manage the emotional distress caused by the stressor.

The Stress, Appraisal and Coping Theory has been instrumental in explaining how employees deal with work stress, but it also has several limitations. One major critique is its overemphasis on individual perception and coping mechanisms while downplaying the role of organizational support systems (Antony et al., 2024; Tran, 2023; J. Wang et al., 2023). Employees who receive strong support from their supervisors and colleagues are often better equipped to handle stress, regardless of their personal coping abilities (Mensah et al., 2023; Pinnington et al., 2024). This suggests that organizational factors play a critical role in mitigating stress, a dimension that the Stress, Appraisal and Coping Theory tends to overlook.

Cultural differences further complicate the applicability of the Stress, Appraisal and Coping Theory. In high power-distance cultures, employees may feel constrained by hierarchical structures and may be reluctant to express stress or seek help (Hameli et al., 2024; Indrayani et al., 2024; Soeprapto et al., 2024). For example, in collectivist cultures, employees may prioritize group harmony over personal well-being, leading to suppressed coping responses and unresolved stress (Bagga et al., 2023; Hadi et al., 2024). This cultural influence means that the effectiveness of coping strategies can vary significantly across different organizational and societal contexts.

Additionally, the Stress, Appraisal and Coping Theory assumes that employees have the autonomy to choose optimal coping strategies. In reality, many work environments are characterized by rigid structures and limited employee autonomy (Soomro et al., 2024; Tran, 2023; Yusuf et al., 2024). In such settings, employees may lack the flexibility to implement effective coping mechanisms, leading to increased burnout and turnover intentions (Borde et al., 2024; Kurniawan et al., 2023; Pimenta et al., 2024). Research also shows that leadership styles can influence how employees perceive and respond to stress. For instance, transformational leaders who provide emotional support and encourage problem-solving can help employees cope more effectively with stress (Agustina et al., 2024; Borde et al., 2024; Sumardjo & Supriadi, 2023).

Transformational Leadership Theory

The Transformational Leadership Theory, introduced by Burns (1978), describes leaders who inspire, motivate, and provide individualized support to their employees. Transformational leaders are characterized by four key behaviors: idealized influence (acting as role models), inspirational motivation (articulating a compelling vision), intellectual stimulation (encouraging creativity), and individualized consideration (attending to employees' individual needs). These behaviors foster a positive work environment, enhance job satisfaction, and reduce turnover intentions by creating a sense of purpose and belonging (Rojak et al., 2024; Shatila et al., 2024; Susanto et al., 2023).

Although transformational leadership has been widely validated in organizational research, it is not without limitations. One critique is its assumption of universal applicability across different cultures and organizational contexts (Kilag et al., 2024; Pham et al., 2023). In high power-distance cultures, employees may prefer directive leadership styles over participative or inspirational approaches (Madi Odeh et al., 2023; Noori et al., 2023). For instance, research shows that in cultures where authority and hierarchy are highly respected, employees may view transformational leadership behaviors such as intellectual stimulation and individualized consideration as inappropriate or ineffective (Asbari, 2024; Purwanto et al., 2023).

Furthermore, the effectiveness of transformational leadership can vary based on organizational size and complexity. In large organizations with multiple hierarchical layers, it can be challenging for leaders to provide personalized attention to every employee (Bagga et al., 2023; Ghorbani et al., 2023; Rojak et al., 2024; Shatila et al., 2024). This raises questions about whether transformational leadership can consistently reduce turnover intentions in complex organizational settings. Empirical studies suggest that the impact of transformational leadership on turnover is moderated by factors such as organizational culture, employee expectations, and job characteristics (Ali, 2024; Ly, 2024).

Additionally, some scholars argue that transformational leadership may lead to burnout if leaders set excessively high expectations or demand continuous innovation (Juyumaya & Torres, 2023; Madi Odeh et al., 2023; Pham et al., 2023; Shatila et al., 2024). In such cases, the positive effects of transformational leadership on job satisfaction may be undermined by increased work stress, ultimately negating its potential to reduce turnover intentions. Therefore, while transformational leadership offers valuable insights into effective leadership practices, its limitations must be considered in diverse organizational and cultural contexts.

METHODOLOGY

This study adopts an integrative literature review approach to synthesize existing theoretical perspectives and empirical findings in the fields of work stress, job satisfaction, transformational leadership, and turnover intentions. The objective is to develop a comprehensive conceptual framework by integrating insights from multiple theories, including the Traditional Turnover Theory, the Stress, Appraisal and Coping Theory, and the Transformational Leadership Theory. By consolidating findings from recent studies, this review provides a structured understanding of how these variables interact in contemporary organizational settings.

To ensure the analysis reflects the latest academic advancements, this study focuses on peer-reviewed journal articles published within a three-year duration from 2022 to 2024. Literature was retrieved from Scopus, Web of Science, and Google Scholar, using keyword searches such as "work stress" and "job satisfaction," "transformational leadership" and "turnover intentions," as well as "employee retention" and "occupational stress." The selection of articles was guided by their relevance to the conceptual relationships examined in this study, particularly those that explicitly explore the interplay between work stress, job satisfaction, leadership influence, and employee turnover. Only papers written in English and published in high-impact academic journals were considered to maintain consistency and quality in the analysis.

After gathering and reviewing the relevant studies, key themes and theoretical intersections were identified to inform the development of the integrated conceptual framework. The analysis involved critically comparing findings from different theoretical perspectives, highlighting areas of convergence and divergence, and recognizing research gaps that need further exploration. This synthesis process allows for a holistic understanding of how transformational leadership moderates the relationship between work stress, job satisfaction, and turnover intentions.

By employing an integrative literature review, this study provides a comprehensive synthesis of recent academic contributions while identifying theoretical and practical implications. The developed conceptual framework serves as a foundation for advancing discussions in leadership research, employee well-being, and organizational retention strategies. It also offers insights that can guide future empirical studies in this area.

THEORETICAL INTEGRATION AND CONCEPTUAL FRAMEWORK DEVELOPMENT

As work environments become increasingly complex, relying solely on a single theoretical framework is insufficient to comprehensively explain the interactions among work stress, job satisfaction, and turnover intention. Therefore, this study attempts to integrate the Traditional Turnover Theory, the Stress, Appraisal and Coping Theory, and the Transformational Leadership Theory to develop a comprehensive integrative conceptual framework of employee behavior. This conceptual framework aims to elucidate how work stress indirectly leads to turnover intentions through job satisfaction and how transformational leadership moderates this relationship.

The Need for Theoretical Integration

Existing studies are often confined to single theoretical perspectives, resulting in fragmented explanations of employee turnover behavior. The Traditional Turnover Theory highlights the direct influence of job satisfaction on turnover intentions (Griffeth et al., 2000; Mobley, 1977) but fails to consider dynamic factors such as work stress and organizational support (Pepple et al., 2023; Pinnington et al., 2024; Soeprapto et al., 2024; Tabak et al., 2024). The Stress, Appraisal and Coping Theory focuses on how individuals manage work stress (Lazarus & Folkman, 1984) but neglects the role organizations play in mitigating stress (Pimenta et al., 2024; Yusuf et al., 2024; Zen, 2023). Meanwhile, the Transformational Leadership Theory emphasizes how leaders enhance job

satisfaction through motivation and support (Noesgaard & Jørgensen, 2024; Ramli et al., 2024; Sumardjo & Supriadi, 2023) but does not delve into how leadership influences the relationship between stress and turnover intentions.

By integrating these three theories, a more comprehensive understanding of employee behavior in complex work environments can be achieved. Combining work stress, satisfaction, and transformational leadership effects helps uncover their interactions and cumulative impact on turnover intentions.

Core Components of the Integrative Conceptual Framework

The integrative conceptual framework proposed in this study consists of several key components. Work stress is widely recognized as a factor that contributes to emotional exhaustion and psychological fatigue, increasing the likelihood of turnover intentions (Galanis et al., 2024; Pinnington et al., 2024; T. Wang et al., 2023; Yuan et al., 2024). When employees face stressors they cannot effectively manage, they are more likely to seek alternative employment (Saberi et al., 2023; Soeprapto et al., 2024). This demonstrates a positive relationship between work stress and turnover intentions.

High levels of work stress also significantly reduce job satisfaction (Feng et al., 2023; Galanis et al., 2024; Jamal et al., 2024; Pinnington et al., 2024). Persistent stress exacerbates dissatisfaction with the work environment, career prospects, and organizational culture, ultimately undermining employee morale and performance (Hur & Abner, 2024; Khan et al., 2024). This highlights a negative relationship between work stress and job satisfaction.

Research consistently shows a negative relationship between job satisfaction and turnover intentions (Griffeth et al., 2000; Mobley, 1977). Satisfied employees exhibit higher levels of organizational commitment and loyalty, making them less likely to leave their jobs (Antony et al., 2024; Galanis et al., 2024; Saberi et al., 2023). Therefore, maintaining high job satisfaction is crucial for reducing turnover intentions.

Furthermore, job satisfaction mediates the relationship between work stress and turnover intentions (Fleischer & Wanckel, 2024; Soeprapto et al., 2024). In this pathway, work stress lowers job satisfaction, which in turn increases turnover intentions (Hadi et al., 2024; Indrayani et al., 2024). This underscores the importance of maintaining job satisfaction to mitigate the adverse effects of work stress on turnover intentions.

Lastly, transformational leadership moderates the relationship between job satisfaction and turnover intentions (Abu Orabi et al., 2024; Cheah & Lim, 2024). In high-stress environments, transformational leaders provide emotional support, motivation, and individualized care, reducing the likelihood that low job satisfaction leads to turnover (Bagga et al., 2023; Rojak et al., 2024; Shatila et al., 2024). For instance, intellectual stimulation encourages employees to find innovative ways to cope with stress, while individualized consideration enhances feelings of belonging and security (Asbari, 2024; Juyumaya & Torres, 2023; Kilag et al., 2024).

This integrative conceptual framework emphasizes the dynamic interactions between work stress, job satisfaction, turnover intentions, and the crucial moderating role of transformational leadership.

Conceptual Framework and Hypothesis Development

Based on the integrative conceptual framework, the following hypotheses are proposed:

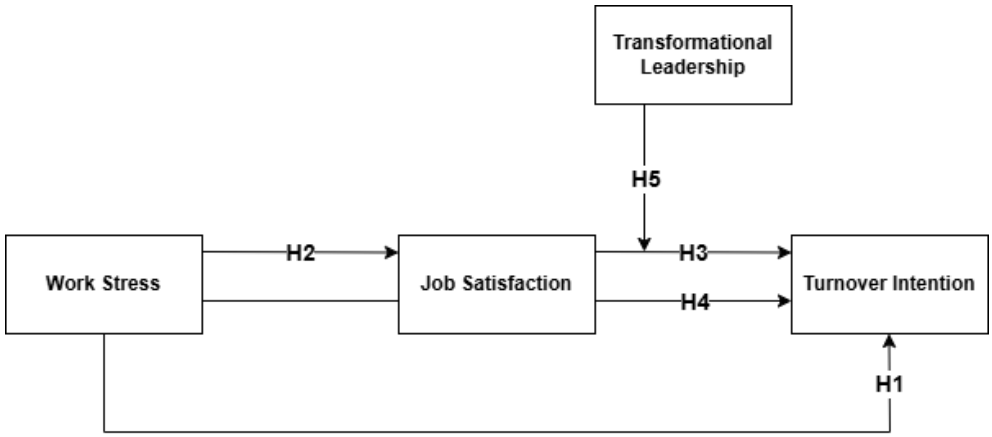

Figure 1: Integrative Conceptual Framework of the Relationships Between Work Stress, Job Satisfaction, Transformational Leadership, and Turnover Intention

Figure 1 illustrates the integrative conceptual framework of work stress, job satisfaction, transformational leadership, and turnover intentions. The arrows indicate the proposed relationships among these variables. Work stress is hypothesized to negatively impact job satisfaction, which in turn increases turnover intentions. Transformational leadership is proposed to moderate the relationship between job satisfaction and turnover intentions by mitigating the adverse effects of low job satisfaction.

H1: There is a positive relationship between work stress and turnover intentions.

Work stress is widely recognized as a key driver of turnover intentions. According to the traditional turnover theory, employees experiencing prolonged dissatisfaction, often exacerbated by high levels of stress, are more likely to develop turnover intentions (Mobley, 1977; Griffeth et al., 2000). Recent studies have extended this view, indicating that emotional exhaustion and psychological fatigue resulting from unmanaged work stress significantly increase the likelihood of employees seeking alternative employment (Jiang et al., 2023; Malik, 2023; Pepple et al., 2023; Winfield & Paris, 2024). Furthermore, the Stress, Appraisal and Coping Theory highlights that individuals who perceive workplace stress as a threat to their well-being are more inclined to consider leaving their job as a coping strategy (Lazarus & Folkman, 1984; Yusuf et al., 2024; Tran, 2023).

H2: There is a negative relationship between work stress and job satisfaction.

High levels of work stress have been consistently shown to diminish job satisfaction. The Stress, Appraisal and Coping Theory emphasizes that persistent stressors, such as heavy workloads or interpersonal conflicts, reduce employees' positive appraisal of their job environment (Lazarus & Folkman, 1984; Jamal et al., 2024). Empirical studies confirm that work stress disrupts employees' emotional well-being and undermines their morale, resulting in dissatisfaction with their roles and organizational conditions (Feng et al., 2023; Hur & Abner, 2024; Galanis et al., 2024). Moreover, research has identified stress as a critical factor that deteriorates employees' perceptions of career prospects and organizational culture, further exacerbating dissatisfaction (Khan et al., 2024; Pinnington et al., 2024).

H3: There is a negative relationship between job satisfaction and turnover intentions.

The Traditional Turnover Theory identifies job satisfaction as a primary determinant of turnover intentions, with dissatisfied employees being significantly more likely to consider leaving their organizations (Mobley, 1977; Griffeth et al., 2000). This relationship has been corroborated by numerous studies, which show that satisfied employees demonstrate stronger organizational commitment and loyalty, reducing their likelihood of leaving their jobs (Antony et al., 2024; Galanis et al., 2024). Furthermore, satisfied employees often experience greater alignment between personal goals and organizational values, which further reduces their turnover intentions (Ribeiro et al., 2023; Saberi et al., 2023).

H4: Job satisfaction mediates the relationship between work stress and turnover intentions.

Research consistently supports the mediating role of job satisfaction in the relationship between work stress and turnover intentions. The Stress, Appraisal and Coping Theory posits that high levels of work stress reduce job satisfaction, which in turn increases turnover intentions (Lazarus & Folkman, 1984; Hadi et al., 2024; Soeprapto et al., 2024). Recent empirical findings confirm this pathway, showing that work stress disrupts employees' positive evaluations of their jobs, creating dissatisfaction that ultimately motivates them to leave (Fleischer & Wanckel, 2024; Indrayani et al., 2024). The mediating effect of job satisfaction highlights the importance of addressing workplace stress to reduce turnover rates.

H5: Transformational leadership moderates the relationship between job satisfaction and turnover intentions.

The Transformational Leadership Theory underscores the ability of leaders to mitigate the adverse effects of low job satisfaction on turnover intentions. By providing emotional support, fostering trust, and offering individualized consideration, transformational leaders create a supportive work environment that enhances employees' sense of belonging and security (Burns, 1978; Bagga et al., 2023; Rojak et al., 2024). Studies show that transformational leaders can buffer the negative impact of dissatisfaction by encouraging innovative coping mechanisms, such as intellectual stimulation and emotional resilience (Asbari, 2024; Juyumaya & Torres, 2023; Kilag et al., 2024). This moderating role is particularly significant in high-stress environments, where leadership plays a crucial role in retaining employees (Madi Odeh et al., 2023; Shatila et al., 2024).

Theoretical Contributions of the Integrative Conceptual Framework

The proposed integrative conceptual framework makes significant theoretical contributions. First, it synthesizes the Traditional Turnover Theory, the Stress, Appraisal and Coping Theory, and the Transformational Leadership Theory to provide a holistic perspective on employee turnover behavior, which previous frameworks have struggled to address comprehensively. By integrating these theories, this framework overcomes the limitations of single-theory models that primarily focus on job satisfaction without considering the dynamic effects of stress and leadership interventions. Beyond leadership and job stress, organizational-level factors such as organizational culture and structure may also influence employee turnover intentions. A supportive culture that prioritizes employee well-being can buffer the negative effects of stress, while rigid structures may amplify dissatisfaction. Additionally, individual-level factors such as psychological capital (e.g., resilience, optimism) and personality traits (e.g., emotional stability) could moderate the relationships in the proposed framework. Employees with high psychological capital may be less likely to experience stress-induced job dissatisfaction, making them less prone to turnover intentions.

Second, the framework underscores the critical roles of work stress and transformational leadership in shaping turnover intentions. It addresses key gaps in existing research, such as the lack of understanding about how prolonged work stress interacts with leadership support to influence employee attitudes over time. This is particularly valuable for high-stress work environments, where leadership behaviors can significantly alter employee outcomes (Galanis et al., 2024; Juyumaya & Torres, 2023; Yasin et al., 2023).

Third, by exploring the moderating effect of transformational leadership, the framework provides actionable insights for organizations. For example, transformational leaders can mitigate the adverse effects of low job satisfaction and work stress by fostering trust, providing emotional support, and offering growth opportunities. This contributes to creating resilient teams and reducing turnover intentions in high-stress settings (Firmansyah et al., 2022; Madi Odeh et al., 2023).

Finally, this integrative approach allows organizations to identify the underlying causes of employee turnover more effectively. It offers practical recommendations, such as optimizing work environments, implementing stress management programs, and developing transformational leadership skills. These strategies not only enhance employee satisfaction and retention but also foster the development of stable, efficient, and sustainable organizational systems.

CONCLUSION AND MANAGERIAL IMPLICATIONS

This study integrates the Traditional Turnover Theory, Stress, Appraisal and Coping Theory, and the Transformational Leadership Theory to develop an integrative conceptual framework that explains the relationships among work stress, job satisfaction, and turnover intentions. The findings indicate that work stress reduces job satisfaction, which in turn increases turnover intentions. However, transformational leadership, through support and motivation, can effectively buffer the negative impact of declining job satisfaction on turnover intentions.

To mitigate turnover intentions, organizations should prioritize reducing employee work stress, especially in high-pressure work environments. Managers can achieve this by redistributing workloads to prevent overburdening employees, improving work processes to increase efficiency, and providing psychological support such as counseling services or stress management programs. Addressing work stress can lead to increased job satisfaction and a reduction in turnover intentions. Research shows that employees who perceive strong organizational support experience lower stress levels, which improves their overall job satisfaction (Cheah & Lim, 2024; Hameli et al., 2024; Indrayani et al., 2024; Soeprapto et al., 2024). Improving job satisfaction is crucial to reducing turnover intentions. Organizations can achieve this by offering career development opportunities, such as training programs and mentorship, improving the work environment by fostering a positive organizational culture, and increasing compensation and benefits to ensure employees feel fairly rewarded for their contributions. Employees with higher job satisfaction are more likely to remain committed to their organizations, while those with lower satisfaction are more inclined to leave (Al-Refaei et al., 2024; Dreer, 2024; Hadi et al., 2024).

Promoting transformational leadership practices among management can also play a significant role in reducing turnover intentions. Transformational leaders can provide emotional support to help employees manage stress, encourage innovation, and recognize employee contributions to maintain motivation. By offering individualized consideration, transformational leaders address employees' unique needs and enhance their sense of belonging. This leadership style can mitigate the adverse effects of job dissatisfaction on turnover intentions, fostering higher levels of commitment and reducing the likelihood of employee departure (Asbari, 2024; Ghorbani et al., 2023; Hilton et al., 2023; Kilag et al., 2024; Rojak et al., 2024).

Transformational leadership also presents unique challenges in cross-cultural management. While this leadership style has shown positive effects in Western cultures, it may face limitations in

high power-distance cultures where hierarchical structures dominate (Ali, 2024; Purwanto et al., 2023). In such cultures, employees may be less receptive to participative and motivational leadership styles and may expect more directive leadership. To address these challenges, managers should balance employee autonomy and organizational authority to align with cultural expectations. Adapting leadership styles to fit the cultural context, providing more structure in high power-distance cultures, and fostering cultural awareness through cross-cultural training programs can help mitigate cultural conflicts and management obstacles (Hur & Abner, 2024; Jamal et al., 2024; Park & Song, 2023).

The impact of work stress and the effectiveness of transformational leadership vary across different industries, requiring tailored leadership strategies. In the high-tech industry, employees often face intense technological change and high workloads. Transformational leaders can use intellectual stimulation to encourage problem-solving and innovative thinking, helping employees manage the pressure of rapid change. Providing continuous learning opportunities and fostering a culture of innovation can alleviate stress and increase job satisfaction (Mensah et al., 2023; Rasheed et al., 2024; Soeprapto et al., 2024). In the traditional manufacturing industry, employees may experience stress from monotonous tasks or lack of career progression. Transformational leaders should focus on individualized consideration to enhance employees' sense of value and belonging. Offering recognition programs, skill development opportunities, and clear career pathways can help improve job satisfaction and reduce turnover intentions (Ekingen et al., 2023; Khan et al., 2024; Pinnington et al., 2024). In the service industry, where employees often deal with emotional labor and high interaction demands, transformational leaders can provide emotional support and create a positive service culture to mitigate stress. Encouraging teamwork, offering stress management workshops, and providing adequate breaks can help maintain job satisfaction and reduce turnover (Domurath et al., 2023; Galanis et al., 2024; Hur & Abner, 2024; Jamal et al., 2024).

This study underscores the importance of integrating multiple theoretical perspectives to understand and manage employee behavior comprehensively. By reducing work stress, enhancing job satisfaction, and promoting transformational leadership, organizations can effectively reduce turnover intentions and foster a committed, motivated workforce. Adapting these strategies to different cultural contexts and industry-specific challenges will enhance their effectiveness and support sustainable organizational growth.

FUTURE RESEARCH DIRECTIONS

Although this study develops an integrative conceptual framework by integrating multiple theoretical perspectives, there are still some limitations and research gaps that warrant further exploration. Future research can deepen and expand this work in the following areas.

Longitudinal Research Application: Future studies should adopt longitudinal data collection methods to track employees' behavior over extended periods of work stress. Longitudinal research offers unique advantages in capturing the dynamic relationships between work stress, job satisfaction, transformational leadership, and turnover intentions. Unlike cross-sectional studies, which provide only a snapshot at a single point in time, longitudinal research can uncover temporal patterns and causality, illustrating how these variables evolve and interact over time (Abdellatif & Bakri, 2023; Alam et al., 2022; Yong & Mustapha, 2023). For example, it can reveal how prolonged exposure to work stress affects job satisfaction and how leadership interventions mitigate these effects over months or years. Such insights are critical for understanding the processes underlying employee behavior and refining the proposed integrative conceptual framework. Moreover, longitudinal data can help organizations implement proactive strategies by identifying early warning signs of declining satisfaction or increasing turnover intentions, ultimately enhancing employee retention and organizational stability.

Cross-Cultural Research: The applicability of transformational leadership as a moderating factor in different cultural contexts remains an open question. In particular, the effectiveness of transformational leadership in high power-distance cultures needs further validation. Future research should explore how cultural values, such as authority dynamics and collectivism, influence the relationship between work stress, job satisfaction, and turnover intentions. Investigating the mechanisms through which transformational leadership operates in diverse cultural settings can enhance our understanding of its universal and context-specific effects on employee behavior. For example, it can expose specific transformational leadership behaviors (e.g., individualized consideration, intellectual stimulation) that are most effective in mitigating stress and improving job satisfaction in high power-distance settings. It can also explore whether intellectual stimulation has a greater impact in cultures where employees expect hierarchical leadership, or whether individualized consideration better addresses employee well-being. Addressing these concerns could provide deeper insights into the applicability of transformational leadership across different cultural contexts.

Expansion of Leadership Styles: While this study focuses on transformational leadership, future research should also consider alternative leadership perspectives such as Servant Leadership and Transactional Leadership. Servant Leadership, which emphasizes the leader's role in serving and empowering employees, may provide additional insights into reducing turnover in high-stress environments. Transactional Leadership, which relies on structured rewards and punishments, could offer a contrasting approach to managing work stress and satisfaction. Comparing these leadership styles with transformational leadership could further refine the current understanding of effective employee retention strategies. For instance, servant leadership, which emphasizes serving employees' needs and fostering a supportive environment, may offer different pathways to mitigate turnover intentions. Similarly, transactional leadership, which relies on clear structures, rewards, and penalties, may provide alternative mechanisms for managing work stress and satisfaction. Including these leadership styles in future studies can enrich the employee behavior model and provide a more comprehensive framework for understanding how various leadership approaches influence turnover dynamics.

By addressing these research gaps, future studies can build on the current model to offer deeper insights and more robust strategies for managing employee retention. These directions will not only enhance theoretical understanding but also provide practical guidance for organizations operating in diverse and dynamic environments. Future empirical studies could employ quantitative approaches such as Structural Equation Modeling (SEM) to test the validity of the proposed framework across diverse industries. SEM would allow for a simultaneous examination of multiple relationships within the model, providing robust statistical support for the hypothesized pathways. Alternatively, qualitative methods such as in-depth interviews could be used to explore employees' lived experiences with transformational leadership and work stress, uncovering nuances that may not be captured through quantitative surveys.

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MICROCRACK SELF-HEALING TECHNOLOGY FOR CEMENT-BASED MATERIALS

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ABSTRACT

Crack self-repair technology of cement-based materials refers to the ability to repair cracks within the cement-based material structure without external repair measures. It can be divided into engineering self-healing technology and intrinsic self-repair technology, depending on the repair mechanism and the presence or absence of additional healing materials. In this paper, the mechanisms and characteristics of various crack self-repair technologies are summarized, the recent research progress on crack self-repair in cement-based materials is discussed, and suggestions for future research directions are proposed. Many researchers have experimentally demonstrated that mineral admixtures offer potential for improving the self-healing ability of microcracks in cement-based materials. However, the self-healing technology involving mineral additives is still in the exploratory stage, with limited and insufficiently systematic research findings. Further studies are needed to evaluate the effects of mineral additives on the self-healing performance of microcracks in cement-based materials, and to identify the composition and characteristic parameters of these mineral materials that enhance self-repair capacity. Such advancements would support the increased recycling of mineral additives, reduce construction waste, lower environmental pollution in the production of cement-based materials, and yield significant social, economic, and ecological benefits.

Keywords:
Cement-based materials, self-healing effect, microcracks, healing mechanism, self-healing concrete, green technology concrete

INTRODUCTION

As one of the most important materials in engineering construction, cement-based materials are prone to cracking due to various factors, which can seriously affect project quality (Kong & Norul, 2025). The traditional manual repair methods are not only costly, but also time-consuming and labour-intensive, gradually revealing significant limitations (Sun et al., 2024). In recent years, transforming the repair of microcracks in cement-based materials from a passive to an active process has become a major research focus among scholars both domestically and internationally. The goal is to address the issue of concrete cracking at its root. Many researchers have confirmed that cement-based materials possess an intrinsic self-healing capability, which allows them to sense microcracks within concrete structures (Li & Norul, 2025) trigger a self-repair mechanism, and restore material properties in real time (Kong & Norul, 2023), thereby extending the service life of the structure (Fernandez et al., 2021). According to the repair mechanism and the presence or absence of external repair materials, the self-healing technologies for cement-based materials can be classified into: Engineering self-healing technologies (e.g., hollow pipe network systems, microcapsules, bacteria and microorganisms, swelling and crystallization additives). Intrinsic self-healing technologies, also referred to as spontaneous or natural self-healing (Liu & Lu, 2023).

SELF-HEALING TECHNOLOGY OF HOLLOW PIPE NETWORK SYSTEM

Mimicking the vascular networks of living organisms, hollow fibers or pipe networks can be used to store and transport self-healing functional components. When cracks form and cause the hollow pipe to rupture, the flowing repair agent is released into the crack, where it coagulates and hardens. In this way, the hollow pipe network system effectively delivers the organic polymer repair agent to the damaged area, enabling autonomous crack repair (Zhang et al., 2020).

Fiber-reinforced concrete materials incorporate appropriate amounts of carbon fiber, steel fiber, glass fiber, or mixed fibers into ordinary concrete to reduce early shrinkage cracks, temperature-induced cracks, and long-term shrinkage cracks in concrete structures. When the concrete is subjected to loading, the fibers help control crack width and inhibit crack formation. The addition of human slag to concrete has been shown to effectively promote crack healing (Eisa, 2020). Similarly, combining rubber scraps and steel fiber in reinforced concrete beams has been found to improve mechanical properties, particularly when more than 10% rubber content is used. Adding polypropylene fiber to foam concrete enhances its resistance to cracking and increases toughness, while incorporating bamboo fiber can reduce or delay crack formation and improve the tensile strength of concrete (Liu et al., 2020).

Hollow fibers also help address the inherent drawbacks of concrete, such as high brittleness and low tensile strength, by altering the internal microstructure, reducing crack formation, and improving both impermeability and durability. However, the high production cost and time-consuming fabrication of fiber materials limit the widespread adoption of this technology.

MICROENCAPSULATION SELF-HEALING TECHNOLOGY

The microencapsulation method was first proposed by White et al. in 2001, and its repair effectiveness is influenced by multiple factors (Zhang et al., 2022):

(1) The total number, size, and degree of dispersion of capsules within the cement-based material;
(2) Whether the capsule material ruptures when the cement-based material cracks;
(3) The type and fluidity of the repair solution inside the capsule;
(4) The causes of cracking in cement-based materials, including crack size and spatial distribution.

In recent years, researchers have conducted extensive and in-depth investigations into microcapsule shell materials suitable for self-healing in cement-based materials. The principle of microcapsule self-healing technology involves encapsulating a liquid repair agent within a microcapsule or hollow fiber, which is then evenly mixed into the concrete. When the concrete experiences stress and microcracks form, the capsule wall ruptures due to mechanical force, releasing the internal repair agent. This agent then flows into the crack and, through capillary action, reacts and solidifies with components in the cement matrix, ultimately bonding and healing the crack (Ren et al., 2020).

Lin et al. (2020), in the preparation of a microencapsulated self-healing concrete, added three types of fluorosilicates as curing agents and found that sodium fluorosilicate exhibited the best self-healing performance. Shen et al. (2020) reported that when a component is damaged, the wall of the microcapsule breaks, releasing epoxy resin into the crack, which heals the damage. The tensile strength recovery rate after repair was 45%. Subsequent studies demonstrated that calcium nitrate microcapsule-based self-healing concrete exhibited significantly higher sealing efficiency in steel fiber-reinforced concrete beams compared to the control group at both 21 and 42 days. The largest sealed crack reached 290 μm (Shang et al., 2020).

The preparation method for microcapsule self-healing concrete is relatively simple and cost-effective. However, microcapsules are prone to rupture during the mixing and vibration processes, which may prevent them from functioning as intended. Therefore, it is essential to develop new

concrete manufacturing techniques to ensure microcapsules remain intact until activated. Additionally, the repair adhesive contained in the microcapsules or fibers should possess adequate bond strength to restore or even enhance the structural performance of the repaired concrete.

BACTERIAL MICROBIAL SELF-HEALING

The earliest research on the introduction of bacteria into concrete dates back to the 1990s, when Gollapudi et al. (1995) first succeeded in implanting bacteria into cement-based materials to induce calcium carbonate precipitation, thereby enhancing the self-healing of cracks. Given the important role of calcium carbonate in the self-healing process of cement-based materials, researchers have sought to increase its formation by introducing bacteria and microorganisms into concrete, thereby exploring new self-healing pathways. This autonomous repair technology, based on biomineralization, has demonstrated effective crack healing performance.

In earlier studies, microbial self-healing referred to the use of aerobic microorganisms that undergo mineralization to generate sediments for crack repair. Calcium carbonate, the product of this reaction, exhibits good compatibility with concrete structures (Xu et al., 2019). Wang et al. (2020) reported that the mechanical properties of self-healing concrete using expanded perlite-immobilized microorganisms decreased with higher carrier content. After 28 days, the concrete cracks were filled, and the compressive strength recovery rate reached nearly 63%.

Despite these promising results, microbial self-healing remains in the laboratory research stage. Microorganisms have strict environmental requirements for growth, which presents challenges for experimental implementation (Zhang et al., 2021). Moreover, the presence of water, oxygen, nutrients, and specific microbial strains significantly affects both the compatibility of microorganisms with the concrete matrix and the durability of the material during the mineralization process.

SWELLING AND CRYSTALLIZATION ADDITIVES SELF-HEALING

Many studies have shown the presence of alum and other compounds in the self-healing products found at fracture sites, which may be attributed to a re-cementation effect. Based on this concept, expansive and crystallization additives have been developed to enhance the self-healing performance of cement-based materials. As hydrophilic substances, swelling and crystallization additives can react rapidly with water to generate crystalline compounds that fill cracks. The inclusion of these crystalline additives significantly improves the self-healing properties of concrete (Rong et al., 2024).

Guo et al. (2019) found that the main factors influencing the impermeability of concrete are the structural morphology and quantity of crystals formed. Yao et al. (2020) reported that the addition of osmotic crystalline waterproofing materials and nano-silica promoted crystal formation at concrete crack sites. Subsequent experiments determined that a water–cement ratio of 0.5 was optimal for internally mixed permeable crystalline concrete, producing the highest number of internal crystals and effectively repairing cracks.

Simultaneously, researchers investigated the effects of calcium-based mineral additives, chemical expansion agents, and crystalline components on the self-healing performance of steam-cured mortar. The results indicated that steam curing, in combination with these mineral additives, significantly enhanced self-healing efficiency. Both crack sealing and impermeability were markedly improved. It was therefore concluded that swelling and crystallization additives, when used in combination with auxiliary materials, can maximize self-healing performance (Zhang et al., 2024).

To summarize, the most commonly studied engineering self-healing methods such as hollow fiber tube systems, microcapsules, bacterial and microbial mineralization, and swelling and crystallization additives can enhance the crack-healing capabilities of cement-based materials.

However, their complex construction processes and high costs hinder large-scale application. Addressing these cost-related challenges remains a critical barrier. Among these methods, only crystallization precipitation-based self-healing has been applied in practical engineering due to its relative simplicity and cost-effectiveness. While international scholars have made notable advancements in crystallization-based self-healing technologies, relevant research outcomes in China remain limited.

INTRINSIC SELF-HEALING TECHNIQUES

Intrinsic self-healing technology, also known as spontaneous or natural self-healing, refers to the inherent repair capability of cement-based materials. This mechanism promotes the automatic healing of early-stage microcracks within the material's structure. The self-repair process in cement-based materials occurs as "unhydrated" cement particles within the crack continue to hydrate, forming insoluble crystalline precipitates. These precipitates contribute to crack closure. At points where cracks are exposed to the external environment, the hydration products react with water and carbon dioxide in the air to form compounds such as calcium carbonate, which accumulate within the crack and assist in restoring the material's integrity either fully or partially (Lv et al., 2024).

The primary mechanism of intrinsic self-healing is attributed to the precipitation of calcium carbonate, as evidenced by the frequent appearance of white calcium carbonate deposits on the outer surface of healed cracks. This is primarily due to the high solubility of calcium hydroxide, a byproduct of cement hydration, which dissolves in water and subsequently reacts with dissolved carbon dioxide to form self-healing crystals. These crystals adhere to the crack surfaces and gradually fill the voids.

One of the most critical steps in the intrinsic self-healing process involves the reaction of dissolved Ca $(OH)_2$ with carbon dioxide in water to form calcium carbonate, which is particularly significant in the later stages of healing. As calcium hydroxide dissolves, the concentration of calcium ions (Ca^{2+}) increases until it reaches supersaturation, facilitating the formation of calcium carbonate precipitates. In open water environments, this reaction is sustained due to the continuous availability of CO_2, allowing carbonates to migrate steadily into the cracks, where calcium carbonate crystallization occurs and progressively fills the voids (Wei et al., 2020).

EFFECT OF MINERAL ADDITIVES ON INTRINSIC SELF-HEALING EFFECT

When incorporated into the structure of cement-based materials, mineral additives serve as environmentally friendly alternatives that not only alleviate environmental pressure but also enhance certain properties of conventional cement-based materials. This improvement depends on the mineralogical composition of the additives and occurs without compromising the structural integrity of the concrete. These additives can further promote the self-healing of microcracks. Although powdered mineral additives, when used as admixtures, come into direct contact with water limiting their active period and reducing their effectiveness in later-stage crack repair, they still exhibit self-healing potential for microcracks that form in the early stages due to shrinkage stress or external forces.

Studies from researchers in various countries demonstrate that using mineral additives in cement-based materials can reduce cement content and material costs. Furthermore, due to their micro-filler effect, pozzolanic activity, and particle packing, these additives enhance the pore structure and permeability resistance of concrete. When cracks occur, calcium hydroxide (Ca $(OH)_2$) within the matrix activates the unreacted mineral particles. This promotes further hydration, enabling the healing of microcracks within permissible widths, thereby restoring both the strength and water resistance of the concrete matrix. However, since some mineral additives consume Ca $(OH)_2$ during

hydration, they may impact the amount of calcium carbonate precipitation, a key self-healing product. This effect warrants further investigation.

Fly ash is the most widely used mineral admixture in concrete. Yu et al. (2023) found that incorporating fly ash improves the workability and durability of concrete, with performance significantly affected by fly ash quality. Their experimental results showed that, under the same strength grade and water cement ratio, Grade I fly ash yielded slightly higher impact wear strength than Grade II fly ash. Similarly, Yin et al. (2020) observed that increasing fly ash content improved the self-healing ability of cement-based materials, largely by refining the internal microstructure. Zhou et al. (2022) also confirmed that different amounts and qualities of fly ash influence not only mechanical properties but also thermal characteristics and early crack resistance. Zheng et al. (2021) studied the effect of fly ash quality and dosage, concluding that high-quality fly ash significantly enhances compressive strength, thermal insulation, and early crack resistance under equivalent dosages.

In addition to fly ash, mineral powder, commonly derived from blast furnace slag is also effective in improving concrete properties. This slag is produced by quenching molten iron slag and then processing it through drying and grinding. Zhang et al. (2019) reported that when slag content is below 30%, the intensity of the A peak in XRD patterns increases slightly with higher slag content. They concluded that a 30% slag replacement level offers the most effective self-healing performance for concrete microcracks. Yu et al. (2019) compared the effects of fly ash and blast furnace slag, finding that while both enhanced self-healing through continued hydration, they had minimal influence on calcium carbonate formation. Nonetheless, mineral powder demonstrated stronger performance as a cement substitute.

When two or more mineral additives are used in combination, they may interact synergistically, turning individual disadvantages into collective advantages and improving the concrete's properties. Research has shown that such combinations can significantly improve the mechanical performance of low-strength concrete, especially with age. For instance, compressive strength measured at 90 days was substantially higher than that measured at 28 days. Wang et al. (2022) investigated the effects of "bimineral" admixtures on the early self-healing properties of cement-based materials. They substituted 10% of the cement with combinations of silica fume, metakaolin, quicklime, an expansion agent, and Na_2CO_3. Nine double-admixture specimens were evaluated under immersion and standard curing through crack observation, permeability testing, and compressive strength tests before and after water curing. Results showed that specimens containing quicklime, silica fume, or metakaolin had higher crack repair rates, with the combination of quicklime and metakaolin achieving a 100% crack repair rate at 28 days. Li et al. (2021) similarly found that replacing cement with blast furnace slag and fly ash improved compressive strength and frost resistance. The materials' pozzolanic characteristics promoted continued hydration of the cement matrix and enhanced self-healing.

CONCLUSION

In summary, the intrinsic self-healing technology of cement-based materials relies on their inherent properties to generate insoluble crystalline precipitates through the continued hydration of unhydrated cement particles in the crack region. This process promotes the autonomous closure of cracks and offers notable advantages, such as simplicity and low cost, when compared to engineering-based self-healing technologies. In the application of cement-based materials, mineral admixtures such as mineral powder, fly ash, silica fume, metakaolin, quicklime, and expansion agents have been shown to influence self-healing performance. These admixtures can reduce early-age strength or cause shrinkage-induced cracking, which in turn can stimulate the self-healing process. However, some mineral additives consume calcium hydroxide $Ca(OH)_2$ during hydration, potentially affecting the

formation of calcium carbonate, a key component in crack healing. This interaction requires further investigation.

Experimental studies have demonstrated that, due to the diverse properties of mineral admixtures, multi-component combinations can offer complementary effects. The synergistic interaction between different admixtures can offset the limitations of using a single type and enhance the overall self-healing capacity of cement-based materials. However, the field of crack self-healing remains in its early stages, and the understanding of the underlying mechanisms and governing laws is still incomplete. As such, significant research is needed to address existing challenges and to develop a more systematic and comprehensive understanding of self-healing in cement-based materials.

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POSITIVE BEHAVIOUR MANAGEMENT STRATEGIES FOR LOW AND HIGH LEVEL DISRUPTIVE MALAYSIAN SECONDARY SCHOOL STUDENTS

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ABSTRACT

Positive classroom management is crucial to achieve the efforts and rationale stated in the Malaysian National Education Philosophy (National Education Blueprint 2013-2025). This study focused on collecting qualitative data by identifying the frequency and the type of low- and high-level disruptive behaviours among students in Malaysian secondary schools. Moreover, it also focused on the current behaviour management strategies used by the teachers and their effectiveness with low- and high-level disruptors. And finally, the study proposed possible positive behaviour management strategies to better manage disruptive behaviours in classroom. The samples were 10 secondary school teachers chosen through the process of snowball sampling. Seven teachers were involved in the interview and three teachers were used for pilot study. Data was collected in the form of in-depth one-on-one audio recorded interview via Zoom and Microsoft Teams. An interview protocol was created to assist the research to stay on track. The collected data was analysed via qualitative data analysis, inductive approach to thematic content analysis and field notes scribes as an alternative to transcription. The findings from the interviews suggested, teachers use both punitive strategies and positive behaviour management strategies to deal with low- and high-level disruptors. The selection of strategies and the effectiveness were based on the batch of students and the type of class. The majority used rewards, praises, communication or rapport building. Some seek the guidance of school authorities such as the discipline and counselling units for uncontrollable behaviours only.

Keywords:
positive behaviour management strategies, disruptive behaviours, secondary school students, classroom management, educational psychology

INTRODUCTION

Classroom setup has been a crucial component in the learning environment as it supported both teaching and learning. According to Monash.edu (2021), the physical atmosphere of the classroom was necessary to enhance the teaching-learning process and prevent behaviour issues. A positive learning environment allowed learners to acquire new skills, which highlighted the significance of classroom management in education. This was especially important in 21st-century education where learning environments had become more complex, influenced by learners' characteristics and broader cultural and psychological factors (Monash.edu, 2021). Classroom management was closely tied to students' learning outcomes. Effective classroom management required teachers to implement specific strategies. Without them, poor classroom management could negatively affect students' academic growth (Calstatela.edu, 2021).

The Malaysian National Education Philosophy (National Education Blueprint 2013–2025) emphasised producing balanced individuals. Teachers, aside from parents, played a vital role in realising this goal by shaping students' potential. For students to meet the aspirations of the education system, teachers needed to manage classrooms effectively (Ministry of Education Malaysia, 2022). As classrooms become more complex and diverse, effective teachers must foster communication, respect, and engagement (Evans & Lester, 2021). However, disruptive behaviours such as defiance and aggression still often impede teaching and strain teacher authority (Reinke et al., 2021; Mazwati et al., 2016). Peer influence also contributes to the spread of disruptive behaviours,

affecting classroom harmony and academic performance (Osher et al., 2022). Disruptive behaviours are context-dependent and can be shaped by societal values, school-family conflicts, and peer pressure (Fakhruddin, 2018). These behaviours range from low-level disruptions like talking or inattentiveness to high-level issues like aggression or violence (Yang & Chen, 2022). Teachers continue to observe behaviours such as excessive talking, wandering, and yelling (Krishnansamy et al., 2019), with peer pressure sometimes escalating into more serious offences like theft or violence (Chow et al., 2023).

Disruptive behaviour has been defined under four categories: interference with teaching, infringement on others' rights, physical or psychological harm, and property destruction (Fakhruddin, 2018). In 2017, the Ministry of Education monitored 402 schools with known disciplinary problems, with 311 having serious issues and 91 classified as 'hotspots' (Chow et al., 2023). These statistics raise concerns about the effectiveness of current disciplinary approaches. Scholars have questioned whether punitive measures comply with the principles outlined in the Convention on the Rights of the Child (Balasingam et al., 2019). Although many teachers rely on punitive methods, they often do so without structured guidance or reinforcement strategies (Mazwati et al., 2016). Despite recognising the ineffectiveness of these methods, teachers continue to use them due to lack of formal training and professional support (Simonsen et al., 2023).

Past studies (e.g., Shen, 2024; Mazwati et al., 2016) showed that teachers' strategies were ineffective, often due to lack of formal training. Many applied the same punitive methods once used on them. Despite realising their ineffectiveness, these were the only tools they knew. Furthermore, corrective measures and harsh punishment were still prevalent in Malaysian secondary schools.

Teachers often felt unrecognised and anxious, yet classroom disruption was not impossible to manage. By identifying accurate strategies, teachers could improve classroom control and student outcomes. The study intended to be a helpful resource for both new and experienced teachers, encouraging a positive approach to behaviour management.

However, the study was not without limitations. Conducted during the COVID-19 pandemic, it faced restrictions due to the Movement Control Order. School closures limited the sample size and the ability to conduct classroom observations. Initially, the researcher intended to involve principals, discipline teachers, and school counsellors from schools in Kajang and Bangi, but these plans had to be modified. The study avoided analysing virtual classrooms, focusing strictly on physical classroom experiences, as the two contexts presented different behavioural patterns. Literature from 2020–2021 was also minimal, further constraining the research scope. Despite these challenges, the study maintained its relevance by focusing on teachers lived experiences with disruptive behaviour in Malaysian secondary school classrooms.

Hence, this paper aimed to address the gap by exploring why existing strategies remained ineffective and by proposing evidence-based positive behaviour strategies for managing both low and high-level disruptions. Moreover, to investigate the behaviour management strategies employed by secondary school teachers and their effectiveness in handling disruptive behaviours. It also sought to suggest positive strategies to better support teachers. The paper focused on qualitative data collection from secondary schools in Malaysia, particularly in Selangor, identifying the frequency and type of disruptions, evaluating current strategies, and recommending better alternatives.

This paper was guided by five objectives: to identify the frequency of low and high-level disruptive behaviours; to identify the types of these behaviours; to investigate current strategies used by teachers; to assess their effectiveness; and to propose positive strategies. The corresponding research questions explored how often these behaviours occurred, their types, the strategies used to manage them, how teachers evaluated their effectiveness, and what additional support might help them manage disruptive students.

The theoretical foundation for this study was drawn from Behavioural Learning Theory, which played a major role in managing classrooms with proper discipline and supporting student learning. This theory focused on the interaction between students and teachers and viewed behaviour as something that could be taught and influenced by external factors. According to Ng et al. (2021),

behaviour was shaped by both innate and inherited factors, and teacher behaviour played a significant role in influencing how students behaved in the classroom. Early behaviourists such as Skinner, Pavlov, Canter, and Watson believed that human behaviour was shaped through the use of rewards and punishments (Bandura, 2001). This theory asserted that individuals learned to repeat or avoid certain behaviours based on observed outcomes and the experiences of others.

In line with the goals and structure of this research, the theory selected to underpin the study was Lee and Marlene Canter's Assertive Discipline Theory (1989). This theory was chosen because it aligned closely with the study's five research objectives and research questions. Assertive Discipline focused on the ability of teachers to act and communicate with students in a calm, controlled, and structured environment (Lee & Marlene Canter, 1989). It was based on the idea that students' misbehaviour often stemmed from unmet needs and desires, and it was the responsibility of the teacher to set clear expectations and limits (Charles & Senter, 2005). Teachers were encouraged to develop a systematic discipline plan and to discuss these expectations and the consequences of behavioural actions with students at the beginning of the academic year (Karasova et al., 2023)

The Assertive Discipline model promoted a humanistic approach to classroom management. It encouraged teachers to maintain a positive and productive learning environment by using specific strategies to address and prevent misbehaviour. The model incorporated a combination of rules, rewards, reinforcements, and consequences (Canter, 2001). Teachers who adopted this model were expected to communicate clearly with students, reinforce positive behaviours, and apply appropriate consequences when necessary. This ensured that both teachers' and students' rights were respected in the classroom, allowing for fair treatment and effective learning (Shen, 2024)

Aliakbari and Bozorgmanesh (2015) described assertive teachers as those who were well-organised, clear about classroom strategies, maintained strong teacher-student relationships, and enforced reward-and-consequence systems consistently (Sultansal et al., 2025). Assertive teachers clearly expressed their expectations, gained positive responses from students, and treated all students fairly. In contrast, less assertive teachers often lacked clarity, appeared indecisive, and struggled to communicate their needs to students. While the Canters initially focused on strong leadership from teachers, they later emphasised mutual respect and the importance of positive recognition, which helped students build constructive relationships with their teachers (Sultansal et al., 2025)

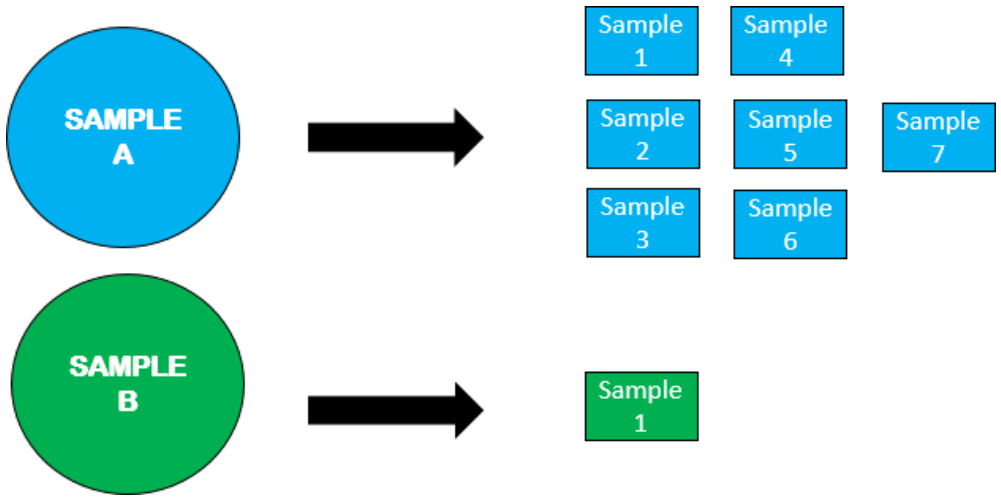
As highlighted by Thilagaratnam et al. (2021), the major concept of Assertive Discipline revolved around the teacher-student relationship. It stressed that both parties had rights and responsibilities within the classroom setting. According to the theory, students had the right to communicate with their teachers and resolve problems in a supportive environment. Assertive Discipline aimed to balance teacher authority with student engagement, leading to a more structured and respectful classroom culture. The application of this theory in the study was intended to address the specific challenges faced by teachers dealing with low and high-level disruptive behaviours, and to support the development of positive behaviour management strategies in Malaysian secondary school classrooms.

METHODOLOGY

This study attempted to investigate the current behaviour management strategies employed by secondary school teachers when handling both low and high-level disruptive behaviours and their effectiveness in reducing the repetition of such behaviours. Furthermore, the study aimed to assist pre- and in-service secondary school teachers by suggesting evidence-based positive behaviour management strategies. A qualitative research design was employed, using in-depth one-on-one audio interviews. According to Almasi et.al., 2021, qualitative research offered a holistic approach that allowed the researcher to explore social scenarios from the participant's point of view. This approach was suitable as it enabled the researcher to understand the frequency and type of disruptive

behaviours, evaluate current strategies, and propose improvements based on lived experiences. The decision to use qualitative methods was supported by Karasova et al., 2023 who asserted that respondents could openly share their thoughts and feelings, resulting in a deeper understanding that could not be captured through closed-question surveys.

The study used non-probability snowball sampling. Due to the COVID-19 pandemic and limited networking, snowball sampling helped the researcher identify 10 secondary school teachers as participants. This included seven for the main interviews and three for the pilot study. The sample was recommended by previous participants, consistent with the nature of snowball sampling.



The participants were experienced in-service teachers from both public and private secondary schools in Selangor. Their experience ranged from 12 to 33 years across subjects such as English, Moral Studies, Life Skills, Science, and Mathematics. The in-service status of the participants helped the study stay relevant and grounded in current classroom realities (Almasi et.al., 2021).

Due to the Malaysian lockdown/stay at home law during the COVID-19 pandemic, interviews were conducted virtually via Zoom and Microsoft Teams. These platforms were selected based on participants' availability and work-from-home schedules. The mode of audio interviews was chosen to respect participants' privacy. The instrument used was a set of five interview questions with multiple sub-questions aligned with the research questions and objectives. Structured questions were used for objectives one to three, and semi-structured ones for objectives four and five. According to amhinternational.com, (2021), structured interviews were suitable when a comprehensive list of questions existed, while semi-structured interviews allowed for deeper probing into participants' thoughts and feelings. Interview protocols and analytical techniques were followed to elicit detailed responses. The interviews were conducted in both English and Malay, with code-mixing and switching where necessary to accommodate participants' preferences and proficiency levels.

The study also used document analysis as a secondary instrument. Public documents included print and electronic journals, online articles, and books. Private documents included syllabi, teaching files, and student evaluation scores. These documents supported a deeper understanding of the context and were selected using guiding principles to ensure relevance. Structured and semi-structured interview data were analysed using qualitative data analysis techniques. The main method was an inductive approach to thematic content analysis. According to Strauss and Corbin (1990, 1998), this method involved identifying, examining, and interpreting patterns and themes within the data. Field note scribes were used as an alternative to full transcription to save time and reduce cost.

Reliability and validity were key considerations. Moreno (2021) defined reliability as the consistency of results over time and their accurate representation of the population. Kirk and Miller (1986) identified reliability in qualitative research as involving repeated measurement consistency, stability over time, and internal agreement. Validity referred to how well the research measured what it was intended to measure. Wainer and Braun (1998) discussed construct validity, while Ng et al., (2021) emphasized the importance of the concept and hypothesis that shaped data collection and analysis. To ensure validity and reliability, a panel of four experts from various academic institutions and professional backgrounds was consulted. The panel reviewed and refined the interview questions to ensure alignment with research objectives. Feedback was provided through written and audio comments, which were summarised and documented.

A pilot study was conducted with three participants: two from a public school in Ampang and one from a private school in Puchong. The pilot study was conducted over three days, from 13th to 15th August 2021. It consisted of three stages: pre-interview, during interview, and post-interview. The pilot interviews helped refine the structure, clarity, and appropriateness of the questions. Adjustments were made to simplify complex terms, focus the questions, and eliminate irrelevant content. The final version of the interview guide was improved and validated based on these insights. This methodology chapter provided a detailed account of the research design, sampling, instrumentation, data collection, analysis, and validation procedures that underpinned this qualitative study.

RESULTS AND ANALYSIS

The findings from the study provided valuable insights into how in-service secondary school teachers managed disruptive behaviours in their classrooms. Through in-depth interviews, teachers revealed the frequency and types of disruptive behaviours they encountered, their strategies for addressing them, and how they assessed the effectiveness of those strategies. The results showed that low-level disruptive behaviours were far more common than high-level ones. All seven teachers interviewed acknowledged experiencing low-level disruptions such as excessive talking, refusal to complete tasks, and inattentiveness. Most reported these behaviours occurred either "sometimes" or frequently, with some indicating they faced them on a daily basis. On the other hand, high-level disruptions such as verbal aggression, defiance, or acts that posed physical danger occurred less frequently. Only one teacher mentioned experiencing high-level behaviours more regularly, while the rest stated they encountered such incidents rarely.

The findings were consistent with existing research by Sørlie and Ogden (2014) which indicated a decreasing trend in low-level disruptive behaviours, as noted in (Shindler, 2021; Ødegård (2017). Teachers recognised that disruptive behaviours were influenced by multiple factors, including students' home environment, peer influence, and the teacher-student relationship. Despite the challenges, most teachers believed that these behaviours could be controlled and reduced with the right strategies. Teachers expressed confidence that with experience, they had learned how to anticipate, understand, and respond to such behaviours more effectively. Some mentioned that experience played a major role in their ability to manage disruptions, suggesting that less experienced teachers might struggle without proper support and exposure.

Teachers were asked to describe the types of disruptive behaviours they classified as low and high level. Low-level disruptions were commonly associated with speaking out of turn, lack of attention, incomplete homework, or moving around the classroom unnecessarily. High-level disruptions, although less frequent, included instances of verbal aggression, talking back to the teacher, and direct challenges to authority. One teacher mentioned that some students displayed a complete disregard for rules, while another described a situation where a student used inappropriate language and refused to participate in classroom activities. The nature of high-level disruptions varied

from school to school, depending on student demographics, school culture, and community background.

When asked how they managed these behaviours, teachers shared a wide range of strategies. For low-level disruptions, they often relied on verbal communication, gentle reminders, and positive reinforcement. Many used motivational phrases, praise, and encouragement to redirect students' attention and behaviour. For high-level behaviours, teachers placed greater emphasis on building a relationship with the student. Strategies included showing empathy, listening to the student's perspective, using a calm tone of voice, and offering second chances. Several teachers highlighted that avoiding harsh tones or sarcasm was essential in de-escalating confrontations and maintaining mutual respect.

In some cases, teachers also adopted a reflective approach, choosing to evaluate their own teaching methods and classroom expectations to ensure they were being fair and inclusive. They acknowledged that misbehaviour sometimes stemmed from misunderstandings, personal issues, or lack of engagement. Hence, part of the strategy involved understanding the root cause and addressing it appropriately. Communication, understanding, and mutual trust were considered vital tools in reducing classroom disruptions.

To determine the effectiveness of the strategies used, most teachers depended on observation. They monitored students' behavioural changes over time and looked for signs of improvement in engagement, task completion, and classroom participation. Teachers noted that low-level behaviours typically improved within a short time frame, usually between one to two months. High-level behaviours, however, required more time and consistent effort, sometimes taking up to a year to show visible change. One teacher emphasised the importance of consistency in applying consequences and following through with discipline plans. Another teacher highlighted how some students responded positively once they felt cared for, suggesting that emotional support could significantly influence behavioural improvement.

The study also found that teachers generally preferred non-punitive strategies over punitive ones. Most of the participants stated that punishments such as scolding, sending students out of class, or public embarrassment were no longer effective. Instead, teachers used more constructive methods, such as giving students roles and responsibilities, involving them in discussions, and offering rewards or incentives. These methods not only improved classroom behaviour but also fostered a sense of belonging and accountability among students. Teachers believed that when students felt seen, heard, and respected, they were less likely to disrupt the class.

Furthermore, the findings supported the application of Assertive Discipline Theory by Canter, which formed the theoretical foundation of the study. The theory emphasised the need for teachers to be assertive, not aggressive or passive when managing behaviour. Teachers who were clear about their expectations, consistent in their actions, and respectful toward students tended to manage classrooms more effectively. This approach allowed students to understand boundaries while feeling respected and supported.

The discussion in Chapter Five reaffirmed that positive behaviour management strategies were more effective in promoting long-term behavioural change. Teachers shared that harsh punishments often led to resentment, rebellion, or further disengagement. In contrast, when teachers treated students with empathy and fairness, students were more willing to listen, comply, and take responsibility for their actions. The emphasis on communication, respect, and consistency aligned with best practices recommended in educational psychology and behaviour management literature.

Teachers also reflected on their need for more structured support and training in behaviour management. While most had learned through experience, they expressed a desire for workshops, professional development, and peer sharing sessions to enhance their skills. This was especially important for novice teachers who lacked the confidence or exposure to manage serious disruptions. Teachers acknowledged that school support systems, including counselling services and administrative backing, played a crucial role in managing behaviour effectively.

Several teachers highlighted the importance of emotional intelligence and patience in managing difficult student behaviours. They explained that not every behavioural issue required disciplinary action. In some cases, simply talking to the student privately or providing a listening ear made a significant difference. One teacher shared that when she listened empathetically to a student who regularly disrupted class, she discovered that the student was facing challenges at home. After showing understanding and offering extra support, the student's behaviour gradually improved. This supported the idea that misbehaviour could often be a reflection of external stressors rather than deliberate defiance.

The findings also pointed to the critical role of school leadership in supporting teachers' efforts. Teachers who felt backed by their principals and disciplinary teams reported higher confidence in implementing classroom strategies. In contrast, teachers who lacked administrative support expressed feelings of frustration, as their efforts were sometimes undermined. This suggested that positive behaviour management was not solely the teacher's responsibility but required a whole-school approach. Some teachers mentioned that peer collaboration also played an important role. When teachers shared their experiences and strategies with colleagues, they felt less isolated and more equipped to handle challenges. This peer support contributed to the collective improvement of discipline practices within the school.

Teachers also noted that establishing classroom expectations early in the academic year helped prevent misbehaviour. By setting clear rules and consistently enforcing them, students were more likely to understand boundaries and respect classroom norms. This proactive approach aligned with Canter's Assertive Discipline model, which advocated for setting expectations from the beginning and discussing the consequences of breaking rules with students in advance. Teachers agreed that consistency was key, students responded best when rules were applied fairly and uniformly, without favouritism or unpredictability.

Another significant point from the discussion was the use of positive reinforcement to encourage good behaviour. Teachers shared that they regularly acknowledged students who followed rules, participated actively, or showed improvement in their conduct. This could be through verbal praise, small tokens, or simple gestures of recognition. One teacher stated that public acknowledgment of a usually disruptive student's effort made the student feel proud and motivated to behave better. This reflected a shift from a punishment-driven model to one that emphasised recognition and encouragement. Teachers believed that reinforcing positive behaviour was more sustainable and effective in promoting long-term change.

While the use of positive strategies was widely accepted, teachers did express some limitations. A few noted that certain students, particularly those with long-standing behavioural issues or complex backgrounds, were less responsive to typical strategies. These students often required tailored interventions involving parents, counsellors, or external professionals. In such cases, classroom-based strategies alone were insufficient. This highlighted the importance of a collaborative support system involving various stakeholders in the education ecosystem.

Despite the limitations faced, including time constraints, large class sizes, and lack of specialised training, the teachers remained committed to improving their practice. Many expressed a sense of fulfilment when their efforts resulted in noticeable behavioural improvements. They described successful behaviour management not just as the reduction of disruptions but as the creation of a safe, respectful, and engaging environment where students could thrive.

In summary, the findings and discussion revealed that positive behaviour management was an evolving practice shaped by teachers' experiences, personal philosophies, and contextual realities. Communication, empathy, consistency, and school support were crucial elements in ensuring the effectiveness of strategies. The study affirmed that while challenges persisted, teachers possessed the insight and adaptability to manage them. The Assertive Discipline Theory continued to provide a valuable framework for structuring classroom management, with its emphasis on clear expectations, mutual respect, and balanced authority. These insights could inform future training, policies, and

support systems aimed at equipping teachers to handle disruptive behaviour in a constructive and confident manner.

CONCLUSION

The conclusion of this study revisited the five research objectives, all of which focused on understanding and improving behaviour management strategies in Malaysian secondary school classrooms. The study aimed to identify the frequency and types of low and high-level disruptive behaviours, explore the strategies teachers used to manage them, evaluate their effectiveness, and propose positive behaviour management techniques. This qualitative study was conducted using snowball sampling and involved interviews with secondary school teachers from one public school in Ampang and one private school in Puchong, Selangor. Prior to the main data collection, a pilot study involving three participants was carried out to test the reliability of the interview questions. Additionally, a panel of four experts reviewed and validated the interview protocol to ensure alignment with the research objectives.

The interviews, conducted over the span of one week, were audio-recorded and analysed using an inductive approach to thematic content analysis. Field notes were used in place of full transcriptions to increase efficiency. Through these interviews, teachers shared their experiences and perceptions about the frequency and severity of disruptive behaviours, ranging from minor disturbances such as talking out of turn to more serious issues like verbal defiance. Most participants reported that low-level disruptions occurred “sometimes” or daily, while high-level disruptions were rare. These findings were consistent with previous literature suggesting that the prevalence of low-level misbehaviour remains a significant concern in secondary education settings.

The study found that teachers used both punitive and positive strategies to address disruptions in their classrooms. However, positive strategies such as communication, praise, and building rapport were generally preferred due to their effectiveness in reducing misbehaviour over time. Teachers observed that good classes responded well to both types of strategies, while weaker classes tended to respond better to positive approaches. Importantly, teachers measured the success of their strategies through observation. Behavioural improvements typically became noticeable within one to two months for low-level disruptions and up to four months or more for high-level disruptions, depending on the student.

The findings also supported the application of the Assertive Discipline model by Canter, which provided the theoretical underpinning for this study. Teachers aligned with the model’s emphasis on setting clear expectations and maintaining consistent communication with students. Many relied on praise, rewards, and calm interactions to manage classroom behaviours, while only turning to school discipline or counselling units when dealing with more severe or uncontrollable behaviour.

In summary, the study successfully achieved its objectives by identifying patterns in classroom behaviour, understanding teacher strategies, and offering practical, evidence-based recommendations. The results showed that positive behaviour management strategies were not only effective but also preferred by most teachers for fostering a respectful and engaging learning environment. These insights could benefit both pre-service and in-service teachers in developing informed approaches to behaviour management tailored to the Malaysian secondary school context.

AUTHORS BIOGRAPHY

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THE EFFECT OF MINERAL ADMIXTURES IN SELF-COMPACTING CONCRETE

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ABSTRACT
With the advancement and progression of modern concrete techniques the focus is no longer limited to achieving high strength, but increasingly emphasises workability, volume stability, and durability, etc. In the field of high-performance concrete, self-compacting concrete represents one of the most significant breakthroughs in recent decades. However, the large quantity of cement required in its preparation not only raises costs and pollutes the environment but also negatively impacts concrete quality. Combining self-compacting concrete with mineral admixtures can address environmental pollution, reduce costs, and enhance performance. Based on this, the article explores the current research and development of different mineral admixtures in self-compacting concrete, summarises and evaluates existing findings, and identifies current research limitations and future directions. The results of this study can provide important references for the formulation and development of self-compacting concrete.

Keywords:
Self-compacting concrete, mineral admixture, research status, development

INTRODUCTION

In the last few years, with the high-speed improvement of the global economy, the urban population has continued to grow and available construction land is severely limited. With the advancement of building techniques, high position buildings and long-span bridges have become increasingly popular, and the requirement for high durability and strength of concrete building structures is growing (Kong & Norul, 2023). Therefore, the concrete industry will also face more technological innovation and progression opportunities. Improving the quality and performance of concrete, and promoting its high-performance, multifunctional, and sustainable development are inevitable trends in the enhancement of concrete methodologies (Kong & Norul, 2025). Self-compacting concrete has emerged in response to these developments.

Self-compacting concrete represents a significant advancement in high-performance concrete (HPC) research in recent decades, owing to its advantages in increasing productivity, improving the working environment, and decreasing construction duration. Therefore, to date, research and progression on mineral admixtures for self-compacting concrete have continued and gradually become a major focus of study both domestically and internationally. This is also an important progression path for future building materials.

SELF COMPACTING CONCRETE

Self-compacting concrete exhibits superior performance compared to conventional concrete. However, self-compacting concrete necessitates a greater quantity of cementitious materials to achieve high fluidity and mitigate segregation and bleeding during transport and placement. Utilising a single type of cement adversely affects concrete quality, resulting in increased early hydration exotherm, greater contraction of the hardened concrete, and a propensity for drying and shrinkage cracks, which undermines the long-term durability and volumetric stability of the concrete (Wang et al., 2024).

Furthermore, the high energy consumption and emissions associated with cement production not only raise the cost of self-compacting concrete but also contribute substantially to carbon dioxide emissions, exacerbating environmental challenges and hindering the advancement of sustainable concrete development. Simultaneously, the swift advancement of industrial technology and population growth have led to a year-on-year increase in industrial waste, resulting in significant accumulation characterised by diverse types and complex mineral and chemical compositions. This accumulation not only pollutes the atmosphere, soil, and water resources, occupying substantial land, but also endangers ecosystems and human health (Liu et al., 2019).

A multitude of studies have demonstrated that incorporating industrial waste to partially substitute cement in self-compacting concrete can mitigate environmental pollution from industrial waste, facilitate energy conservation and emission reduction, and promote resource reutilisation. Furthermore, it can lower concrete costs, and more importantly, the incorporation of industrial waste substantially influences the efficacy of self-compacting concrete by filling the spaces within the paste, diminishing its water consumption, and enhancing both water secretion and overall segregation of the concrete. The water secretion and segregation of self-compacting concrete are improved, enhancing its overall performance which makes the quality and use of concrete more reliable and convenient. Consequently, to concurrently advance the eco-friendly development of the social economy and satisfy the requirement for high powder content in self-compacting concrete, auxiliary cementitious materials exhibiting volcanic ash properties are typically used to partially substitute cement in the formulation of self-compacting concrete (Xiong, 2023).

THE IMPORTANCE OF MINERAL ADMIXTURES IN SELF-COMPACTING CONCRETE

Self-compacting concrete exhibits superior performance compared to conventional concrete. However, the substantial quantity of cement required in its formulation not only elevates costs but also amplifies its carbon footprint (Sun, 2021). Studies indicate that utilising industrial waste as mineral admixtures in self-compacting concrete might mitigate secondary environmental contamination, decrease concrete costs, and enhance the diverse properties of self-compacting concrete.

Regarding the application of mineral admixtures in self-compacting concrete, the objective is to investigate the effective utilisation of industrial waste in the formulation of high-performance self-compacting concrete. This study will offer reference and technical assistance for the formulation of high-performance concrete, the construction, and the safe operation of associated projects, which holds substantial practical value for the sustainable advancement of the concrete industry.

RESEARCH STATUS AND DEVELOPMENT OF MINERAL ADMIXTURES IN SELF-COMPACTING CONCRETE

The active influence of mineral admixtures on the properties of self-compacting concrete has perpetuated ongoing study and advancements in this area. The commonly used mineral admixtures for self-compacting concrete currently include industrial waste such as fly ash (Zhang &Wang, 2024), slag powder (Gan et al., 2023), silica fume (Xu et al., 2024), rice husk ash (Huang, 2021), limestone powder (Wang, 2021), etc. In the last few years, natural volcanic ash materials have also been studied and applied in self-compacting concrete (Gong et al., 2024), however, due to the different types of admixtures, the effects on the performance of concrete are also different. Currently, research on self-compacting concrete with mineral admixtures is still in its infancy, and new problems are constantly being discovered during the research process, which urgently need to be solved by researchers.

FLY ASH

Fly ash enhances the workability and strength of concrete when used as an additive. Nonetheless, varying grades of fly ash exhibit substantial disparities in phase composition, chemical composition, microstructure, and both chemical and physical properties. Consequently, the influence on the performance of self-compacting concrete exhibits significant variability.

Concerning the impact of fly ash content on the efficacy of self-compacting concrete, Ye (2022) investigated the impact of fly ash content on the workability, mechanical properties, and impermeability of self-compacting concrete, as well as its thermodynamic properties via thermogravimetric analysis. Similarly, Zhang and Wang (2024) investigated the impact of varying fly ash dosages on the impermeability and mechanical qualities of self-compacting concrete. The research results all indicate that the addition of fly ash can effectively improve the workability and impermeability of self-compacting concrete; Under the conditions of a curing age of 7 days and 28 days, the compressive strength of concrete specimens decreases as fly ash content increases; When the fly ash content is 20%, self-compacting concrete has the optimal performance. However, the above research on the prediction model of the performance of fly ash self-compacting concrete is insufficient, as it only considers dosage while ignoring the influence of various factors such as fly ash quality and admixture types, and the types of performance studied are not comprehensive enough.

Furthermore, as public awareness of environmental conservation grows, recycled coarse aggregate self-compacting concrete has emerged as a prominent research focus in recent years. Zheng (2024) and Dong et al. (2023) used recycled concrete aggregates instead of natural aggregates and industrial waste instead of cement to prepare eco-friendly recycled self-compacting concrete. The influence of different water cement ratios, replacement rates of recycled coarse aggregates, and mineral admixtures on the performance of recycled self-compacting concrete was analysed. It is believed that the addition of mineral admixtures can compensate for the adverse effects of recycled coarse aggregates (Li & Norul, 2025) and effectively improve the workability and mechanical properties of recycled self-compacting concrete.

MINERAL POWDER

As one of the common mineral admixtures, mineral powder not only has a lower cost than cement, but also meets the national standards for waste utilisation. Additionally, mineral powder exerts a lubricating influence on concrete mixtures, significantly enhancing their fluidity. The particle size of mineral powder is smaller than that of cement, allowing it to efficiently occupy the voids between cement particles, hence reducing porosity in concrete and enhancing its compactness and homogeneity. Consequently, the investigation of the impact of mineral powder on the efficacy of self-compacting concrete has consistently been a focal point of interest for researchers.

In terms of work performance, Gan et al. (2023) analysed the effects of different dosages of mineral powder on the flowability and anti-segregation of concrete using slump tests, sieve analysis tests, and V-funnel tests. It has been proven that mineral powder is beneficial for improving the flowability of self-compacting concrete mixtures. Reddy et al. (2020) found that when no more than 40% mineral powder is added, the filling capacity and gap permeability of self-compacting concrete augment with an increase in mineral powder content, however, the anti-segregation performance diminishes.

Conversely, certain academics assert a contrasting perspective: Ofuyatan et al. (2020) observed that when the mineral powder concentration rose from 0% to 30%, the slump expansion of self-compacting concrete diminished from 590mm to 560mm, but the T500 transit time escalated from 5.65s to 6.05s. Secondly, mechanical properties are also a focus of research for many scholars at home and abroad. Ahmad et al. (2020) found that when the water cement ratio is 0.40, using 10%, 20%, and 30% mineral powder as substitutes for cement slurry can increase the compressive strength of self-compacting concrete by 4%, 18.4%, and 19.8%, respectively. Esfahani et al. (2021) found that when the water cement ratio was 0.35, using mineral powder instead of 15%, 30%, 45%, and 60% cement slurry increased the compressive strength by 18.7%, 22.7%, 13.2%, and 11.2%, respectively. This is because using mineral powder instead of cement slurry can reduce the pores between cement matrix, effectively improve the microstructure of concrete, and thus enhance the compressive strength of concrete. Tadi &Rao (2022) showed that when the mineral powder content increased from 0% to 60%, the compressive strength of self-compacting concrete increased by 4% to 14.4%. Prasanna et al. (2021) also found that replacing 0%-80% of cement with mineral powder resulted in a maximum 28 day compressive strength at a mineral powder content of 20%, with an increase of 4%. But when the amount of mineral powder exceeds 20%, the 28 day compressive strength decreases with the increase of mineral powder content, with a maximum decrease of 22%. Selvarani &Preethi (2021) also obtained the same result, that when the added mineral powder exceeds a certain critical point, the compressive strength gradually decreases.

For the study of mineral powder and other mineral admixtures, Liu (2019) selected fly ash and slag powder as admixtures for self-compacting concrete, and studied the influence of different dosages, grades, and forms of admixtures on the performance of self-compacting concrete. Single or compound admixtures of fly ash and slag powder were carried out, focusing on the workability, strength, drying shrinkage, and hydration products of self-compacting concrete. The economic benefits of self-compacting concrete with single or compound admixtures were also analysed.

In the following research, the types and amounts of mineral admixtures can be increased, and other properties of self-compacting concrete can be further studied. Similarly, Zhou et al. (2020) also believed that fly ash and mineral powder have high economic and social benefits. Based on C30 self-compacting concrete, a mix design was carried out, and fly ash and mineral powder were used to replace cement. The study investigated the effects of single addition of fly coal (0-40%), single addition of mineral powder (0-40%), and combined addition of 40% mineral powder and fly ash on the workability of self-compacting concrete. This article mainly studies mineral admixtures with a dosage of 0-40%, and no research has been conducted on admixtures with a dosage higher than 40%. Further research is needed to investigate the impact of larger dosages on self-compacting concrete.

Due to the large amount of self-compacting concrete binder and low water cement ratio, shrinkage cracking is prone to occur during construction, which affects the durability of concrete structures. Therefore, Xiao (2023) studied the effects of single addition of fly coal, single addition of mineral powder, and composite addition of fly ash and mineral powder on the hardening and durability properties of self-compacting concrete. They conducted flowability tests, mechanical performance tests, shrinkage performance tests, and carbonation tests, The final conclusions may offer a theoretical foundation for the engineering use of self-compacting concrete. Wang et al. (2022) found that the addition of fly ash and mineral powder increased the first cracking time of self-compacting concrete, but at the same time, it also increased the water evaporation of self-compacting concrete, leading to an expansion of the cracking area of self-compacting concrete. In addition, when

the dosage of blended mineral powder exceeds that of fly ash, the effect of increasing the cracking area by 1 day with blended mineral powder is more significant. The above research differs from other scholars' attention to the workability and mechanical properties of self-compacting concrete, with a focus on hardening and durability. However, there are relatively few types of research on mineral admixtures. In subsequent studies, other mineral admixtures can be selected as objects for further research.

SILICA FUME

Adding silica fume to concrete preparation can not only improve the cohesiveness of the mixture, but also significantly enhance the mechanical properties, durability, frost resistance, impermeability, and chemical corrosion resistance of concrete. At the same time, it can inhibit alkali aggregate reactions (Almusallam et al., 2004; Zhang, 2015).

Regarding the study of silica fume in self-compacting concrete, Li et al. (2019) examined the mechanical properties of silica fume in self-compacting concrete and determined that using silica fume enhances both compressive and tensile strength. Wang et al. (2020) designed three different mix proportions for three different strength grades of concrete, C40, C60, and C80, with a total of nine mix proportions. By conducting compressive strength tests on concrete mixed with silica fume with different silica contents, the influence of silica fume with different silica contents on the compressive strength of concrete was analysed. Hua (2022) replaced fly ash, cement slurry, and cement with different dosages and qualities of silica fume, and studied its influence on the workability, mechanical properties, hydration process, pore structure, and microstructure characteristics of ordinary concrete and self-compacting concrete. The aforementioned studies only analysed the effect of silica fume on the performance of concrete, without considering other mineral admixtures, which is relatively single and limited.

In concrete production, solid waste silica fume is commonly utilised as a replacement for cement and fly ash. Zhang and Zhu (2022) discovered that substituting up to 10% of cement with silica fume markedly enhances the compressive strength of the paste at 3 days, minimally diminishes the increase in compressive strength at 7 days, and maintains a superior compressive strength at 28 days compared to the control group. Nagrockien et al. (2019) investigated that at a water-to-cement ratio of 0.47 and a silica content of 93.35% in silica fume, substituting 2.5%, 5%, 7.5%, and 10% of cement with silica fume led to increases of 3.5%, 9.1%, 10.1%, and 13.4% in the 28-day compressive strength of concrete cubes relative to a silica fume content of 0%. Das et al. (2020) investigated the impact of substituting fly ash with lime and silica fume on the composition, strength, and microstructural characteristics of geopolymer concrete. The research findings demonstrate that an increase in silica fume level correlates with heightened slump and extended setting time of geopolymer concrete. Simultaneously, when the silica fume percentage is 2%, the compressive strength achieved by substituting fly ash is maximised, and the microstructure is notably denser.

In the investigation of combining silica fume with various materials, Yin et al. (2021) performed workability, compressive strength, and flexural strength tests on self-compacting concrete using single fly ash, compound fly ash, and silica fume, confirming the beneficial effects of mineral admixtures on the performance of self-compacting concrete. Xie et al. (2021) investigated C30 and C50 concrete, examining the impact of individual additions of silica fume, fly ash, mineral powder, and silica fume on the workability and mechanical qualities of the concrete. The conclusion indicated that in medium to high-grade concrete, the workability and mechanical qualities improved when silica fume, at a ratio of 1:3 and 1:4, substituted cement dosage. Xu et al. (2024) formulated self-compacting high-strength concrete utilising 530 kg of cementitious materials, with a mass ratio of 15:25:60 for fly ash, slag, and cement. Substitute cement with 3.0%, 4.5%, 6.0%, 7.5%, and 9.0% silica fume, respectively, and examine the influence of silica fume content on the workability and mechanical qualities of self-compacting high-strength concrete. Studies indicate that using a suitable quantity of

silica fume enhances the workability of self-compacting concrete, decreases expansion duration, and elevates the degree of expansion; Properly incorporating silica fume into self-compacting concrete can enhance its compressive strength.

It can be found that researchers predominantly examine the impact of silica fume on the workability and mechanical properties of self-compacting concrete, whereas there is comparatively limited investigation into its carbonation resistance, microcracking, corrosion resistance, and self-shrinkage.

LIMESTONE POWDER

Limestone powder replaces some cement and other mineral admixtures in concrete preparation, fully utilising the "micro aggregate filling effect" and "morphology effect" of limestone powder. Proper addition can improve the workability of concrete to a certain extent.

Regarding the study of workability and mechanical properties, Cao (2020) replaced cement, fly ash, and slag powder with ultrafine limestone powder, and experimentally studied the effects of different dosages of ultrafine limestone powder on the workability and mechanical properties of self-compacting concrete. The study concluded that an appropriate substitution of ultrafine limestone powder improves filling ability, gap permeability, and the basic mechanical properties of self-compacting concrete. Elemam et al. (2020) used the central composite design method to design and optimise the mix proportion of self-compacting concrete with fly ash, silica fume, limestone powder, and water reducing agent. The artificial neural network model was used to verify the experimental results and establish a performance prediction model for self-compacting concrete. Research has found that increasing the dosage of fly ash improves the workability of self-compacting concrete and reduces the amount of water reducing agent used, but it does not enhance compressive strength; The increase of silica fume content improves the anti-segregation performance and compressive strength of self-compacting concrete, but it will increase the amount of water reducing agent used; limestone powder improves the anti-segregation performance, but is not conducive to the progression of compressive strength.

For the study of durability and shrinkage performance, He (2022) conducted experiments utilising various water-cement ratios and stone powder mass fractions. The findings demonstrate that self-shrinkage escalates as the water-cement ratio diminishes and the stone powder mass fraction intensifies; when the water-cement ratio ranges from 0.30 to 0.37, its impact on drying shrinkage is negligible. A moderate quantity of stone powder has no impact on drying shrinkage, however a mass fraction of 20% of stone powder results in a significant increase in drying shrinkage. A predictive model for self-shrinkage and drying shrinkage of self-compacting concrete, accounting for the effects of water-cement ratio and stone powder mass fraction, was developed based on experimental data. Alaghebandian et al. (2020) studied the durability of self-compacting concrete and mortar prepared by ternary or quaternary blending of cementitious materials such as silica fume, natural zeolite powder, and limestone powder in simulated marine environments. The results show that the water absorption rate of self-compacting concrete slurry is the lowest when the quaternary compound is added; Silica fume and natural zeolite powder have a significant impact on durability.

CONCLUSION

The incorporation of industrial waste as an internal admixture in self-compacting concrete can help mitigate environmental pollution and reduce production costs, while also enhancing material performance in line with sustainable development strategies. Effective usage can yield significant economic and social advantages. The number of studies on durability is the second most studied aspect by scholars and currently the vast majority of research focuses on impermeability, relatively

neglecting other evaluation indicators of durability, such as frost resistance, erosion resistance, carbonation of concrete, alkali aggregate reaction, etc. Moreover, there is a paucity of studies regarding the microstructure and shrinkage characteristics of self-compacting concrete, and research that holistically addresses workability, mechanical properties, durability, shrinkage performance, and microstructure of self-compacting concrete is virtually nonexistent.

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AN EVALUATION OF FLOOD MITIGATION USING SWMM MODEL IN A RESIDENTIAL AREA IN MUAR, JOHOR.

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ABSTRACT
Flood risk has been on the rise over the years globally. In Malaysia, 10% of the land is susceptible to flooding. The Muar River basin in Johor is one of Malaysia's major rivers prone to severe flooding. Hence, it is crucial to conduct an evaluation of flood mitigation measures on developed sites periodically to minimize the risk. This study aims to offer an assessment of the flood mitigation measures at a residential area in Muar, Johor. A storm water management model by EPA-SWMM is adopted to analyse potential flood issues in the area. During the analysis, the stormwater runoff behavior associated with the rainfall precipitation and the land uses of the study site was analysed and discussed. The event-based simulation would be based on the most severe hourly rainfall precipitation from year 2020 to 2022. The simulation outcome showed signs of flooding at the study area under 2 hours of consecutive rainfall averaging 60mm/hr, and with the inclusion of the proposed solution, results showed improvement of the storm drainage network in flood mitigation capability. The improvement saw a decrease in bottleneck stormwater drainage utilisation from maximum capacity to about 80% under the most severe stormwater runoff volume.

Keywords:
Flood Mitigation, Flood Prevention, Flooding root cause, Stormwater Runoff, Peak Flow, SWMM

INTRODUCTION

Compared to the annual average flood occurrences from 2009 to 2018, the occurrence of flood events worldwide has seen a 30% increase, with 5,110 casualties. In addition, it has caused the world an estimated loss of 155 billion Malaysian Ringgit. In Malaysia, 10.1% of the land, home to 5.7 million people, is exposed to the risk of flooding. States like Sarawak, Selangor, and Perak were among the most affected by flooding in 2020 (CRED, 2021). In Johor, the Muar River basin has also been one of the major rivers in Malaysia that is prone to major flooding. The flood event on 19th December 2006 holds the record for the highest flood depth in the state over the past 40 years.
The rise in flood event occurrences has raised concerns about whether the existing flood mitigation system design is sufficient to handle rainfall runoff due to surrounding urban development and climate change. The increase in precipitation may render the current drainage system ineffective, as the excess water will overflow the banks, leading to flooding (Syed and Mohammad, 2023). The Urban Stormwater Management Manual for Malaysia (MSMA) used to determine rainfall patterns and intensities may not reflect recent rainfall trends in the study area (Bong et al., 2021). Findings by Abustan et al. (2008) indicate that rainfall-runoff behavior varies between sites, and careful planning of land applications should be considered. Hence, the lack of studies evaluating flood mitigation in the study area may understate the risk of future flooding.

From a global perspective, floods occur more frequently than other natural disasters such as droughts, earthquakes, extreme temperatures, storms, and wildfires. In 2019 in particular, flood events increased by 30% compared to the annual average from 2009 to 2018. Furthermore, floods were the deadliest natural disaster in 2019, causing 5,110 casualties and resulting in an estimated global economic loss of 155 billion Malaysian Ringgit (CRED, 2021). Previous research found that 5.7

million Malaysians were exposed to the risk of flooding, occurring in 10.1% of Malaysia's land area. The annual monetary loss is estimated at RM1.15 billion. Based on the records, Sarawak had the highest number of recurring flood events at 225 cases, followed by Selangor (132 cases) and Perak (100 cases) (Pusat Ramalan dan Amaran Banjir Negara, 2021).

Manual calculation procedures for stormwater runoff are tedious and complex, often time-consuming and prone to errors. Fortunately, advances in information technology have enabled complex stormwater runoff analysis through computerized calculations. Numerous software programs in the market, such as HEC-HMS, HEC-RAS, and SWMM-based programs, provide solutions for stormwater design and analysis in complex terrain conditions. Each program has its advantages and disadvantages, and users should understand the program's limitations when analyzing the study area. According to Febrianto et al. (2023), the SWMM model is the most suitable for representing flood conditions. The SWMM model recommends implementing a polder system as a drainage improvement, as it can divide flow into two collectors and reduce load accumulation.

In this study, EPA-SWMM is selected for flood mitigation evaluation due to its excellent program stability, high compatibility with add-on modules for advanced analysis, and its open-source platform, which allows customization to meet specific engineering requirements. Considering the availability of long-term data that may influence the analysis, an event-based rainfall-runoff approach will be applied. Event-based rainfall-runoff has also been shown by Hossain et al. (2019) to produce better outcomes when using EPA-SWMM.

The objectives of this study are to identify the potential root causes of flooding in the study area, located in a residential neighbourhood in Muar, Johor. During the analysis, the peak flow rate will be determined using event-based rainfall-runoff modeling with EPA-SWMM. Then, the flood mitigation measures in the area will be evaluated.

THE STUDY AREA

The study area is situated in a residential area in Taman Maharani Ayu, Muar, Johor, at latitude 2°04'23.9"N and longitude 102°33'41.0"E, as stated in Figure 1. This study area covers approximately 29 acres and consists mostly of residential development in the form of double-storey landed residential units and low-rise apartments, with a small portion allocated to commercial and light industrial use nearby.

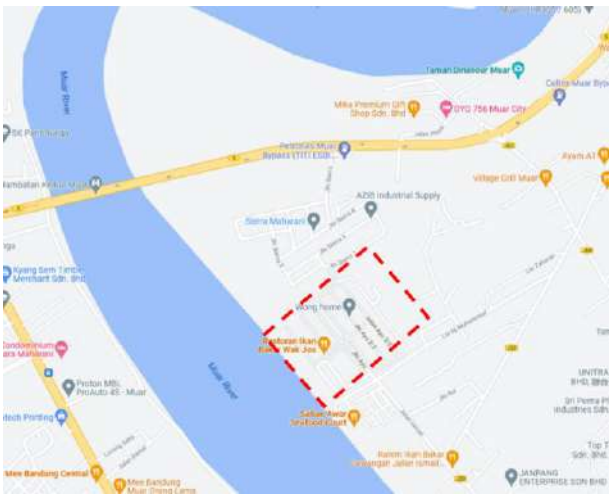

Figure 1: The location of study area

In the state of Johor, the Muar River Basin is an important subject of research due to its geological position and frequent flooding. It is one of the major rivers in Malaysia, with a 6,600 km² catchment area and spanning 329 km in length. The river crosses the states of Pahang, Melaka, and Negeri Sembilan, and discharges through the southwest of Johor into the Malacca Straits. Between 1980 and 2010, a total of 29 severe flood events occurred in the river basin. Based on the analysis, most of these floods took place during the North-East Monsoon season between November and March. The study recorded the highest rainfall intensity on 19th December 2006, with a staggering 301 mm in a single day. This was one of the most severe floods in Johor over the past 40 years, reaching a maximum flood depth of 6.56 m (Yuen Chen et al., 2013; Syed and Mohammad, 2023).

Flood events with occurrence intervals greater than the return period of current flood protection measures are projected to increase across all continents under all considered specific warming levels, leading to a widespread rise in flood hazard. The monsoons are significant factors in determining rainfall patterns in Malaysia. Each monsoon affects the coasts directly facing it and produces intense convectional rain, accompanied by highly variable winds and thunderstorms (Yuen Chen et al., 2013). It is evident that most regions in Peninsular Malaysia experience the highest total number of rainfall days in August. Among these, the eastern region recorded a greater total number of rainfall days compared to other regions (Tan and Yusoff, 2022). A survey by Diya (2014) showed that improper drainage systems, pollution, mismanaged urbanisation, and environmental factors are the top three perceived causes of flooding by the public. Moreover, the characteristically flat terrain limits the rapid drainage of surface water. Combined with extensive impervious paving, this often results in the rapid accumulation of standing water following heavy rainfall (Onifade et al., 2023).

STORMWATER MANAGEMENT MODELLING IN THE MARKET

The EPA Storm Water Management Model (SWMM) has been widely adopted as a runoff modelling tool by water specialists and academic researchers. It is a simulation model developed by the United States Environmental Protection Agency to utilise computers for analysing either single rainfall events or long-term simulations of runoff quantity and water quality in both urban and rural areas. The advantages of SWMM include being freely available to the public, offering strong programme stability, highly customisable modelling, and compatibility with various add-on components for detailed analysis. Nevertheless, SWMM has certain limitations, such as the inability to input data in DWG format, limited compatibility with GIS compared to alternative programmes, and an inability to process calculations when pipelines have a reverse slope (Hlustik, 2017).

EPA-SWMM was used by Junaidi et al. (2018) to evaluate the adequacy of the urban drainage system at a hospital in Padang, located in the Sungai Sapih District. Due to the availability of hourly rainfall data, the authors adopted the Mononobe Method to generate IDF curves for subsequent analysis using a hyetograph. Parameters were simulated using EPA SWMM 5.1 under several scenarios representing current and potential future conditions in terms of land-use changes and drainage upgrades. The simulation outcomes indicated that the current design could not accommodate present and future runoff scenarios. Based on the SWMM results, the authors concluded that Indonesia's current design guidelines require improvement and recommended the collection of more rainfall and drainage data to enhance the accuracy of outcomes.

EPA-SWMM was also adopted by Gambi et al. (2011) to assess potential solutions for reducing flow peaks in receiving waters as part of a redevelopment plan for the old fruit and vegetable market in the city centre of Bologna. The implementation of retention basins, green roofs, and infiltration tanks was simulated using SWMM. The findings demonstrated that the proposed solutions were effective in reducing water volume flows by up to 50%, allowing a reduction in the diameter of discharge pipes leading to the wastewater treatment plant. However, the authors noted that proper

maintenance of the implemented solutions is essential to ensure their long-term effectiveness in managing runoff.

It was also used by Kian et al. (2021) to analyse stormwater runoff rehabilitation for an integrated bio-ecological drainage system located at the academic complex of Universiti Teknologi Petronas. Two bioretention ponds and a new diversion channel were proposed for the flood-prone study area. The simulation results indicated that the mitigation strategy effectively attenuated flow discharge through the integration of the implemented structures. The authors recommended applying best management practices within the EPA-SWMM parameters to generate results that comply with the MSMA standard.

METHODOLOGY

Overall Approach

The study area was modelled using EPA-SWMM 5.2, one of the most widely used software tools among academic researchers and engineering consultants due to its ability to simulate hydrological processes in both rural and urban settings. Hourly rainfall precipitation data from the years 2020 to 2022 was selected and used to simulate the runoff behaviour of the study area, as provided by the Department of Drainage and Irrigation Malaysia (DID). The model requires several parameters to simulate flooding in the study area, such as topographical data, soil data, drainage layout, and rainfall data. The overall approach undertaken in this study is illustrated below:

1. Literature review
2. Data collection from relevant parties and departments
3. Delineation of the drainage network and sub-catchments within the study area
4. Calibration of the SWMM model
5. Execution of SWMM simulation
6. Analysis of simulation outcomes
7. Outlining the main findings of the research
8. Presentation of conclusions and recommendations

For data collection, the topographical data and drainage layout were retrieved from the infrastructure designer. The soil data from the site investigation report was obtained through relevant geotechnical consultants. Rainfall data was accessed via the online portal of the Department of Irrigation and Drainage (DID).

In SWMM, flow routing is governed by the momentum equations and the conservation of mass to analyse unsteady flow. In this study, Dynamic Wave Routing is adopted for modelling the study area due to its performance in producing the most accurate theoretical outputs. It offers advantages over other routing options in determining overflow within the drainage system, whereby the overflow quantity is converted into a constant surface area, which then acts as input to the downstream junction.

For infiltration modelling, the Curve Number Method has been selected due to its relatively simple data requirements. This method only requires input values such as the curve number and the time required for fully saturated soil to dry completely. It is particularly suitable for studies with limited data availability and where less time is available for computation and calibration.

The drainage layout was subsequently imported into SWMM, sub-catchments were delineated, and the drainage system was established in accordance with the design, as shown in Figure 2.

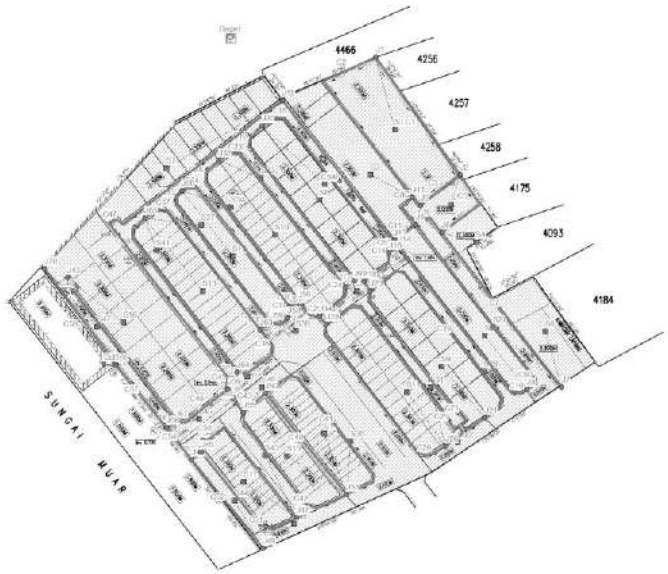

Figure 2: SWMM Modelling

Runoff Equation and Calculation in EPA-SWMM

The EPA-SWMM treats each sub-catchment surface as a non-linear reservoir. As shown in Figure 3, rainfall precipitation and flows from upstream catchments are used as inflow parameters. Surface runoff, infiltration, and evaporation are categorised as outflows. Hence, the runoff is calculated according to the equation below: -

$$Q_{net} = Q_{inflow} - Q_{outflow}$$

Where:-

Q_{net} is net flow under the effect of inflow and outflow.
Q_{inflow} is the inflow expressed in m^3/s
$Q_{outflow}$ is the outflow express in m^3/s

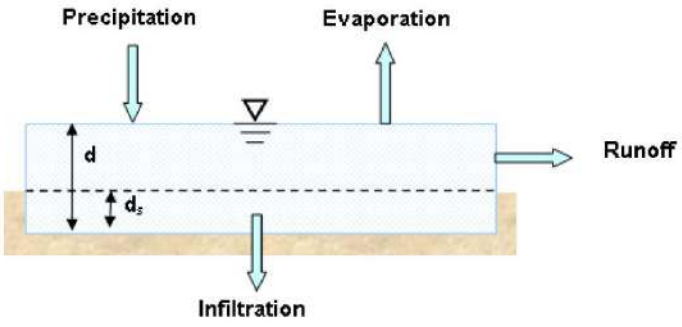

Figure 3: Runoff Model Concept

In SWMM, the flow rate for drainage, pipe culvert and sub-catchment are determined using manning equation: -

$$Q = (1/n) * A * R^{(2/3)} * S^{(1/2)}$$

Where:
n is manning roughness coefficient;
A is the cross-sectional area of flow;
R is the hydraulic radius of flow;
S is the gradient/slope

RESULT AND DISCUSSION

Simulated Result

The rainfall-runoff data for the simulation were recorded over two consecutive rainy days, beginning at 2:00 p.m. on 12/07/2020 and ending at 10:00 a.m. on 13/07/2020. This period represents the highest rainfall intensity recorded throughout the year 2020. During this time, 22 low-lying areas around the research site were affected by flash floods, resulting in damage to property and infrastructure (Astro Awani, 2021). In addition, the rainfall station is located 2 km from the project site, which is sufficiently close to accurately reflect the rainfall intensity at the research location. For these reasons, the selected rainfall data is deemed suitable for evaluating the flood mitigation capability of the research area.

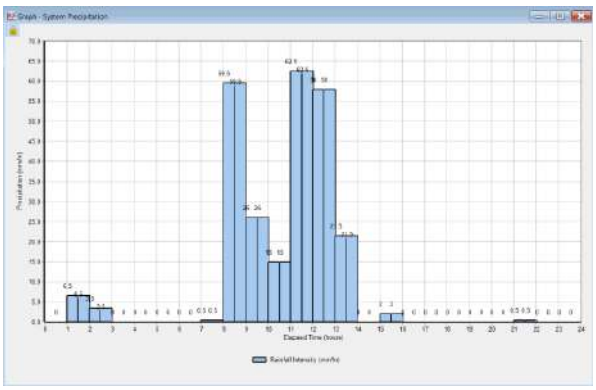

Figure 4: Rainfall Intensity Data

Referring to Figure 4, the total precipitation during the simulation period was 255 mm/day, with the highest hourly rainfall intensity of 62.5 mm occurring between the 12th and 13th hour of the dataset. This intensity is categorised as "Very Heavy" under the Rainfall Intensity Categorisation by the Department of Irrigation and Drainage Malaysia (DID, 2022).

Runoff Quantity Continuity	Volume hectare-m	Depth mm
Total Precipitation	2.658	255.500
Evaporation Loss	0.000	0.000
Infiltration Loss	0.089	8.595
Surface Runoff	2.572	247.300
Final Storage	0.001	0.052
Continuity Error (%)	-0.175	

Flow Routing Continuity	Volume hectare-m	Volume 10^6 ltr
Dry Weather Inflow	0.751	7.511
Wet Weather Inflow	2.572	25.721
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	3.292	32.922
Flooding Loss	0.012	0.118
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.019	0.193
Continuity Error (%)	-0.002	

Figure 5: Simulation Analysis

From the simulation outcome, 96.7% of the rainfall was discharged primarily through surface runoff, while the remainder infiltrated into the soil layer. This implies that the surface area of the research site is largely impervious and requires an efficient stormwater drainage system to manage off-site discharge. As the site is developed, with buildings and paved roads, the observed rainwater discharge pattern corresponds with the nature of such a development mix. As the proportion of impervious surfaces increases, both total runoff and peak runoff gradually rise, while infiltration decreases. This pattern is commonly observed in urban environments, where greater imperviousness reduces soil absorption and increases surface runoff (Zhao et al., 2021).

In this simulation, the runoff continuity error was less than 1%, and the flow routing continuity error showed minimal difference between total inflow and outflow. Both continuity errors are within acceptable limits for application in this study.

Potential Root Cause of Flooding

Impervious Area

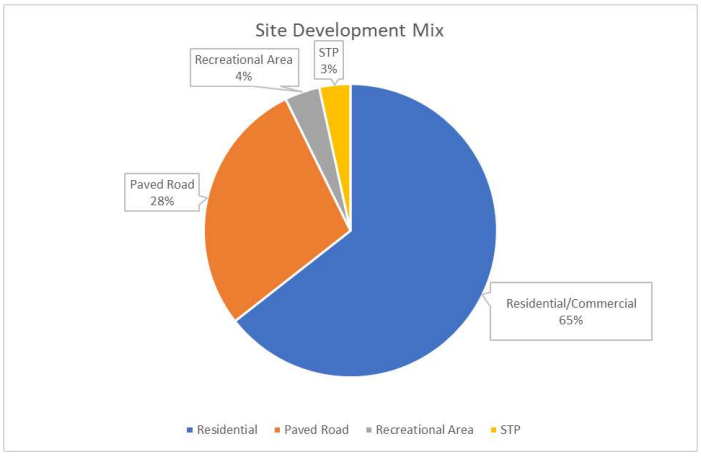

Figure 6: Site Development Mix

Research findings from Figure 6 show that 65% of the land use comprises residential and commercial buildings, while 28% is allocated to paved roads. Both types of land use are conventionally constructed with impervious materials such as roof tiles, road pavements, concrete flooring, glass awnings, and similar surfaces. As a result, 93% of the land use in the study area is classified as highly impervious.

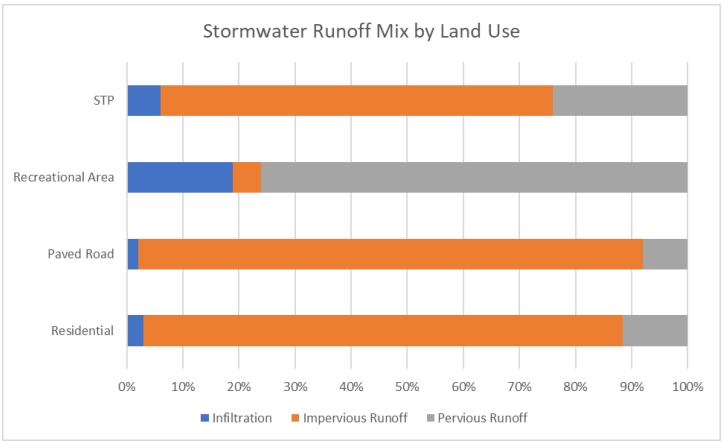

Figure 7: Stormwater Runoff Mix by Land Use

As shown in Figure 7, more than 80% of stormwater from residential, commercial, and paved road areas experienced direct runoff into the nearby drainage system. In contrast, for recreational areas with 95% pervious surface, approximately 20% of the stormwater infiltrated into the soil layer, while about 70% ran off through the pervious surface. Research findings from Iqbal, M. (2022) indicate that urbanisation has a direct relationship with impervious surface coverage—higher proportions of impervious areas significantly increase stormwater runoff rates, especially during heavy rainfall

events. From a macroscopic perspective, the excess water can exceed river capacity and cause flooding in adjacent low-lying areas. When combining the analysis of the site development mix and the stormwater runoff characteristics, it is evident that the research site is susceptible to flooding due to a lack of pervious surfaces and water retention facilities, which are essential for acting as detention mechanisms to moderate the stormwater runoff rate before it is discharged into the drainage system. As a result, flash floods may occur during consecutive heavy rainfall.

Drainage Design

Figure 8: Bottleneck Stormwater Mitigation Path

Referring to Figure 8, the simulation based on the rainfall data showed that stormwater runoff from the sub-catchments is routed through their respective drainage networks and converges at Node J39. The nodes marked in red and drainage segments highlighted in yellow indicate sections of the stormwater mitigation path that are approaching or have reached their maximum depth during the period of 62.5 mm/hr rainfall intensity. The drainage lines highlighted in green also exhibit higher flow depths compared to other segments of the drainage system.

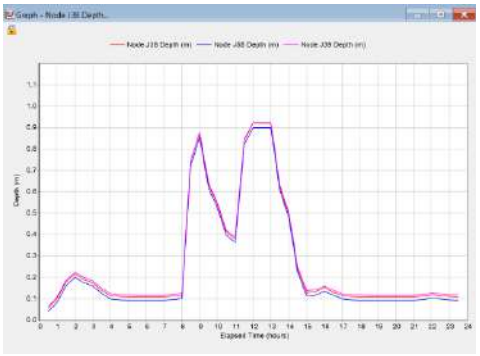

Figure 9: Node J38, J39 and J55 vs Elapsed Time

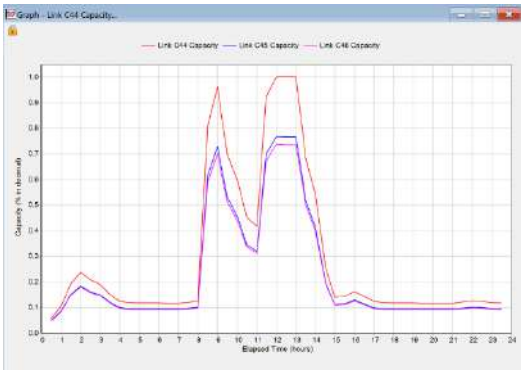

Figure 10: Bottleneck Drainage Capacity

Referring to Figure 9, the nodes (manholes) J38, J39, and J55 are experiencing higher water depth levels compared to other manholes in the network. The flow depth peaked between the 12th and 14th hour of the rainfall dataset. The total rainfall precipitation of 120.5 mm nearly saturated the capacity of the nearby drainage system, resulting in elevated water depth levels as observed in the simulation output.

The capacity of the drainages (conduits) relative to the manholes is illustrated in Figure 10. It shows that Drainage C44, located between nodes J39 and J55, was operating at maximum capacity during the period of heavy rainfall.

This aligns with the flooding analysis, which indicated that Node J55 experienced flooding, with a total flood volume of 117 m³. Flooding at this node occurred at the 12th hour, when the inflow exceeded the maximum capacity that Drainage C44 could handle. As a result, the total flood volume of 117 m³ is expected to impact part of the nearby residential area and paved road.

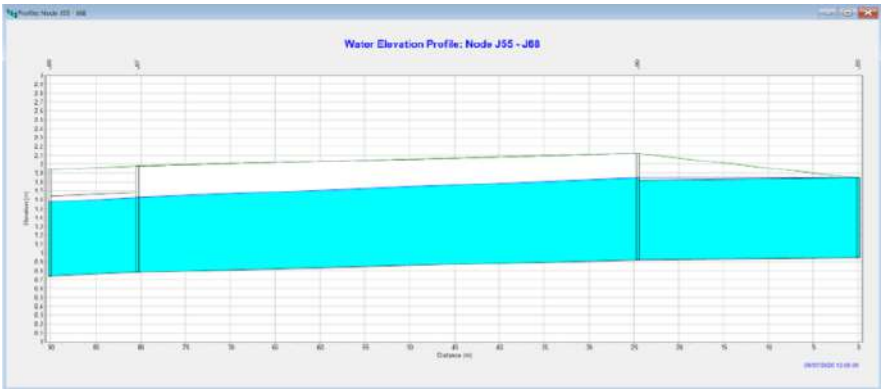

Figure 11: Water Profile from Node J55 to J68

Figure 11 shows the water level profile of the drainage system from the flooded node to the second-last discharge point at Node J68. The figure indicates high water depth in the drainage segments between Node J55 and J39, as well as between Node J67 and Node J68. These drainage segments consist of box culverts located beneath the paved road.

Based on the analysis of drainage utilisation during heavy rainfall, several drainages are also approaching high utilisation, and a bottleneck has been identified around the manhole (Node) J39. Therefore, it is necessary to address this bottleneck by either proposing a diversion or upgrading the drainage capacity to reduce the volume of flow routed through this critical section. Additional mitigation measures, such as permeable pavements, green roofs, infiltration trenches, and other water retention solutions, should also be considered to reduce the volume of runoff being discharged directly into the drainage network.

Peak Flow Rate

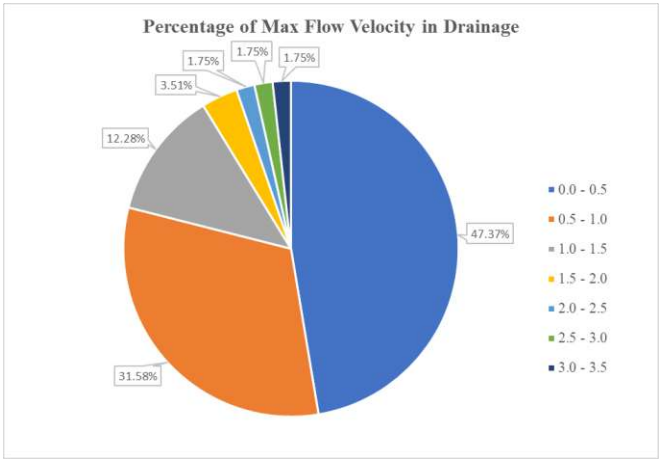

Figure 12: Peak Flow Velocity

The peak flow rate for all drainage paths mostly occurred between the 11th and 12th hour of the rainfall simulation data, during which total precipitation reached 120 mm. During this period, the inflow generated by precipitation was approximately 12,500 m^3. The peak flow velocities for the drainages were determined through simulation using the rainfall data. According to the results shown in Figure 12, 78.95% of the drainages exhibited flow velocities below 1.0 m/s.

The maximum velocity identified was 3.14 m/s, occurring at Drainage C55. Flow velocity is a critical factor that can contribute to soil erosion and scouring within the drainage system. It is important to monitor this parameter and reduce it if velocities exceed 4.0 m/s. In this simulation, all velocities were within the recommended maximum average flow velocity of 4.0 m/s, as specified in Table 16.3 of the MSMA 2nd Edition (DID, 2012).

Effectiveness of Flood Mitigation Measures

The research site may be exposed to the risk of major flooding due to the high proportion of impervious surfaces and the current drainage design. Therefore, it is necessary to review the existing flood mitigation measures in the study area and explore possible methods to improve the site's preparedness against flood risk. The water table at the site is generally high, primarily because the study area is located close to the Muar River. As a result, the high-water table and soil saturation levels render the implementation of most Best Management Practices (BMP) unsuitable (DID, 2012). An upgrade of the stormwater drainage system, particularly at the bottleneck flow path, is proposed to enhance the site's flood resistance capability.

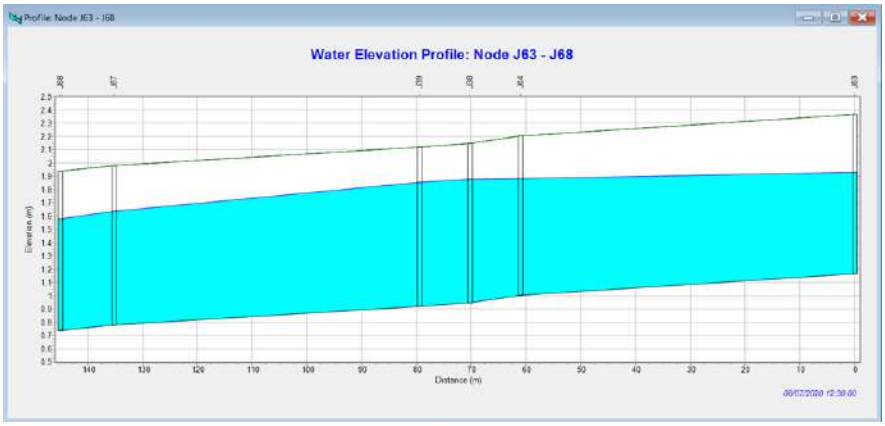

Figure 13: Water Profile after Upgrade (Node J63 -J68)

By upgrading the drainages at the bottleneck section between Node J63 and J68 from a depth of 0.9 m to 1.2 m, the maximum utilisation rate of the bottleneck drainage path was reduced from 100% to approximately 80%, as shown in Figure 13. As a result, the proposed drainage upgrade will enhance the resilience of the stormwater mitigation network, allowing it to better withstand even heavier rainfall events than those modelled in this research study.

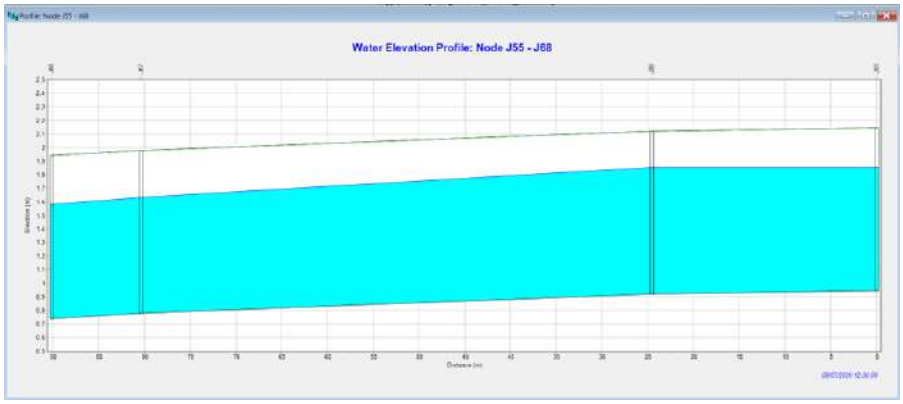

Figure 14: Water Profile after Upgrade (Node J55 - J68)

On the other hand, the utilisation of Drainage Link C44, as shown in Figure 14, also improved after being upgraded from the original depth of 0.9 m to 1.2 m. With the increased depth, the box culvert drainage is no longer constrained in handling the volume of stormwater runoff generated from the respective sub-catchments, which comprise residential, commercial areas, and paved roads.

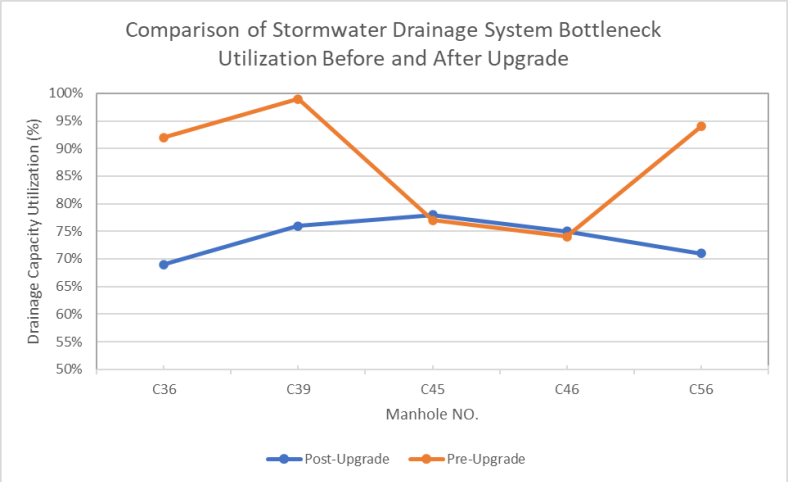

Figure 15: Comparison of Drainage Utilization

`The comparison in Figure 15 shows that overall utilisation after the stormwater drainage upgrade has been reduced by approximately 20%, providing additional capacity in the event of rainfall intensities exceeding the 62.5 mm/hr applied in this research study. Nevertheless, although the existing flood issue has been minimised through the upgrade, the runoff path remains a bottleneck, as there is no alternative mitigation route within the network leading to the outlet.

CONCLUSION AND RECOMMENDATIONS

Based on the analysis of the study area and the simulation results assessing peak flow and flood mitigation effectiveness, it can be concluded that the area is highly vulnerable to flooding, primarily due to the extensive impervious surface coverage and limitations in the existing drainage system design. However, the flood risk can be mitigated through drainage system upgrades, particularly at bottleneck sections such as Manhole (Node) J39.

The analysis showed that 79% of the drainages exhibited flow velocities below 1.0 m/s under the most intense rainfall event used in this study. The peak velocity recorded was 3.14 m/s, which remains well within the allowable limit of 4.0 m/s as specified in the MSMA 2nd Edition.

Furthermore, future studies should incorporate a broader range of rainfall data and collect more comprehensive site-specific information to enhance model calibration. This will ensure more accurate flood risk assessments and the development of more effective mitigation strategies.

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FIRE HAZARD RISK ASSESSMENT OF CLADDING MATERIALS USED IN FACADE SYSTEMS IN MALAYSIA

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ABSTRACT

In the era of modernization, the façade construction industry places increasing emphasis on producing buildings that are visually appealing to consumers. To meet these aesthetic demands while ensuring constructability, engineers have developed a range of lightweight façade materials, among which aluminium composite panels (ACP) are particularly prominent. ACPs are widely used and highly valued for their customizability, allowing them to be tailored to the specific requirements of clients. However, achieving a lightweight design often involves trade-offs in material composition. One such compromise is the incorporation of a polyethylene (PE) core a cost-effective and low-density alternative to more fire-resistant materials. This substitution has been linked to several catastrophic façade fire incidents globally, as the PE core can significantly accelerate fire propagation across building exteriors. In light of these concerns, this study conducts a thermal performance analysis of ACPs manufactured from various combinations of two grades of aluminium 3000 series and 5000 series and three types of PE cores: low-density (LD), high-density (HD), and fire-retardant (FR). The thermal analysis was conducted in accordance with the British Standard BS 8414 Part 1 (2017) using Finite Element Modelling (FEM) through the ABAQUS software platform. The results reveal that none of the tested ACP configurations satisfied the thermal performance criteria established in BS 8414 Part 1 (2017), regardless of the aluminium grade or PE core type. This finding highlights the urgent need to integrate additional fire-preventive layers or materials in ACP-cladded façade systems to ensure compliance with safety standards. Furthermore, the study explores the prevalent use of ACP in ongoing construction projects, as well as the preventative strategies implemented by BOMBA Malaysia (the Malaysian Fire and Rescue Department) to mitigate the risks associated with flammable façades. These insights were gathered from a local façade consultancy firm, offering a practical perspective on how the construction industry in Malaysia is responding to the ongoing fire safety challenges posed by ACP systems.

Keywords:
ABAQUS, Aluminium Composite Panel (ACP), Thermal Analysis, BS 8414 Part 1 (2017), Façade Fire, Flammable cladding

INTRODUCTION

The use of cladding materials in façade systems has raised significant concerns regarding fire safety, particularly in high-rise buildings located in urban centres such as Malaysia. This issue has gained increasing attention following a series of high-profile fire incidents worldwide, prompting engineers and architects to reassess the fire performance of commonly used construction materials. According to Sifat et al. (2024), fire hazard risk assessments are essential to ensure that façade materials do not contribute to the spread of fire or compromise the safety of building occupants. Their study revealed that although certain cladding materials are popular for their aesthetic appeal and insulation properties, they often demonstrate inadequate fire resistance, making them hazardous during fire events. Specifically, the research identified commonly used materials in Malaysia, such as polyethylene (PE) and aluminium composite panels (ACP), which exhibited variable fire performance, thereby highlighting the urgent need for stricter fire testing protocols and regulatory oversight.

The issue of façade fire safety in Malaysia is further exacerbated by the lack of comprehensive local regulations addressing the fire performance of cladding materials. As Abdullah (2021) notes, while some international fire safety standards are referenced in practice, there is a

pressing need to localize these standards to reflect the environmental and construction conditions specific to Malaysia. Abdullah emphasizes the development of context-appropriate national codes, especially for densely populated urban areas where high-rise buildings are prevalent. Similarly, Redzuan (2020) found that despite the existence of national guidelines, enforcement and compliance remain inconsistent. The study also observed that cost-efficiency is often prioritized over safety, with developers opting for cheaper, fire-prone materials without conducting adequate fire risk assessments posing a serious threat to public safety. The combination of substandard material selection, the absence of localized fire regulations, and weak enforcement mechanisms has contributed to a growing fire risk in Malaysia's urban construction sector. To address these challenges, Sifat et al. (2024) advocate for the implementation of rigorous fire testing procedures and the establishment of regulatory frameworks tailored to local conditions. They further stress the importance of raising industry awareness and promoting education on façade fire safety. By enhancing the fire resistance of cladding materials and ensuring compliance with both national and international safety standards, the risk of fire-related disasters in Malaysian buildings can be significantly mitigated.

LITERATURE REVIEW

Façade and Cladding

Derived from the French word face, the term "façade" refers to the external appearance or outer surface of a building. With significant advancements in construction technology, it is now possible to manufacture complex façade elements with high precision. This development has expanded the range of façade products available, allowing for customised solutions to suit diverse architectural projects. Beyond enhancing the visual appeal of buildings, façade components also serve various functional roles, including waterproofing, ventilation regulation, thermal and acoustic insulation, and UV protection. Additionally, façade systems can be constructed using various methods, such as ribbon window systems and curtain wall systems, which incorporate high-performance materials (Kim, 2011).

While the continuous curtain wall system is a common and visually striking feature in high-rise buildings, various cladding materials may also be used as alternatives. These include perforated panels, timber, fibre cement, terracotta, stucco, aluminium solid panels, and aluminium composite panels (ACP) (Bradtmueller & Foley, 2014). However, the selection of materials must be made with careful consideration of both the design requirements and the local climatic conditions. Certain materials may be unsuitable for extreme environments. For instance, due to its lightweight and low-density characteristics, ACP may not be ideal for regions with extremely high temperatures. In such cases, materials like terracotta, which have higher melting and boiling points, may be more appropriate (Cohen, 1992). In the Malaysian context, ACP cladding has gained widespread popularity, largely due to its ability to withstand the country's consistently hot and humid climate while requiring minimal maintenance (Byrnes et al., 2019).

Aluminium Composite Panels, ACP

Aluminium composite panels (ACP) are widely favoured in façade design due to their high degree of customizability and the wide variety of available configurations. These features enable ACPs to fulfil diverse client specifications while significantly enhancing a building's aesthetic appeal, often creating a more visually striking effect than traditional paint finishes (Abdullah, 2018). Additionally, ACPs are considered a cost-effective solution, particularly when purchased in bulk, which further contributes to their popularity in the construction industry. A standard ACP panel typically has a total thickness of approximately 5 mm, comprising a polymer core (2–3 mm) sandwiched between two

aluminium sheets (each 0.5–1.0 mm thick). Both the aluminium layers and the core are available in various grades and compositions. The aluminium sheets are commonly manufactured from the 3000- and 5000-series alloys, each offering distinct mechanical and chemical properties (Latsa, 2015). The polymer core is typically composed of polyethylene (PE), available in three main variants: low-density PE (PE-LD), high-density PE (PE-HD), and fire-retardant (FR) PE. However, alternative configurations also exist, such as ACPs with an aluminium honeycomb core inserted between the aluminium layers. This type of ACP offers enhanced structural integrity and improved fire resistance (Yuen et al., 2021).

Properties of 3000 and 5000 Series Aluminium

As noted by Latsa (2015), both the 3000-series and 5000-series aluminium alloys exhibit very similar mechanical and chemical properties, with the primary difference being their chemical compositions. Table 1 presents the chemical compositions of the two alloys, while Table 2 illustrates the thermal conductivity values for both aluminium grades.

Table 1: Chemical composition of 3000 and 5000 series aluminium alloy (EN 573-3 Aluminium and Aluminium Alloys - Chemical Composition and Form of Wrought Products - Part 3: Chemical Composition,2003)

Alloy designation	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Zn**	**Ti**
Alloy 3000 (EN AW-3105)	0.6	0.7	0.3	0.3-0.8	0.2-08	0.2	0.4	0.1
Alloy 5000 (EN AW-5005)	0.3	0.7	0.2	0.2	0.5-1.1	0.1	0.25	-

Table 2: Thermal Conductivity of 3000 and 5000 series aluminium alloy (BS EN 1706 Aluminium andAluminium Alloys - Chemical Composition and Mechanical Properties, 2020)

Alloy designation	**Thermal Conductivity (W/mºC)**
Alloy 3000 (EN AW-3105)	171
Alloy 5000 (EN AW-5005)	200

Properties of Polymer Cores used in ACP

Although there are various options for manufacturing Aluminium Composite Panels (ACP), such as using Bakelite or polyester as the core material, polymer cores remain the most commonly available option in the market. As mentioned earlier, these polymer cores are typically classified into three variants: PE (LD), PE (HD), and FR, with FR being the most recent to be introduced commercially. The thermal conductivities of the three core types are presented in Table 3 below.

Table 3: Thermal Conductivity of polymer cores used in the production of ACP (Askeland & Wright, 2016;Hansen & Bernier, 1972)

Polymer Core	**Thermal Conductivity (W/mºC)**
PE(LD)	0.33
PE(HD)	0.45
FR	0.50

Flammability risk of ACP

Due to the nature of Aluminium Composite Panel (ACP) cladding, it has been shown to be highly combustible in recent years. This is primarily attributed to the material properties of the polyethylene (PE) core and the behaviour of fire, especially in high-rise buildings where wind loads intensify flame spread. Since PE cores begin to melt at approximately 370ºC, the molten material subsequently ignites and contributes to the rapid propagation of fire (Askeland & Wright, 2016). Moreover, when burned, PE cores release toxic fumes, making evacuation more difficult and hazardous. In addition, research has shown that a higher organic content in the ACP core correlates with an increased peak heat release rate during façade fires (McLaggan et al., 2021). As a result of these factors, the number of fire incidents exacerbated by ACP cladding has increased in recent years, following the rising demand for the material.

Cases of Fire Outbreaks Caused by Flammable Façade

The cases of building fires influenced by flammable façades worldwide are highlighted in Table 4 below. The façade fires listed in the table date back to the early 1990s, during the initial adoption of Aluminium Composite Panels (ACP). At that time, ACP was primarily manufactured to replace heavier and more expensive building materials, offering the advantage of bulk transport and easier on-site installation (Chen et al., 2019). Furthermore, it is evident that in most of the cases cited, ACP with a polyethylene (PE) core was used as the cladding material. However, the occurrence of these incidents demonstrates that, despite the apparent advantages of ACP such as cost efficiency and ease of installation it also poses significant risks, leading to substantial damage and loss.

Table 4: Cases of Building Fire Outbreaks Exacerbated by Flammable ACP

No.	Location	Year	Cladding Material	Cause of fireoutbreak	Casualties
1	Knowsley Heights, Liverpool, United Kingdom	1991	Aluminium composite panels with a mineral core were installed in an unventilated façade system.	Arson. The lack of a horizontal cavity within the system led to the rapid spread of fire, causing the building to burn like a "furnace," according to eyewitness accounts.	0 casualties, all 60 occupants were evacuated in time.
2	Garnock Court, Irvine, Scotland	1999	PVC cladding	A lit cigarette that was improperly disposed of set fire to the cladding.	5 injured, 1perished
3	Television CulturalCentre (CCTV Complex), Beijing,China	2009	Mixture of Titanium and Zinc alloy	The use of illegal and unregulated fireworks caused flames to propagate from the lower floors, eventually engulfing the entire 34-storey building within 20 minutes.	7 individuals were injured, and 1 perished of the 8 people involved, 7 were firefighters, including the individual who lost their life.

4	Shanghai Apartment, China	2010	Aluminium composite panels (ACP) were fitted in a system that used polyurethane (PU) as insulation.	Welding sparks from untrained workers during renovation works ignited the bamboo scaffolding, which then spread to the cladding, engulfing it in flames within four minutes.	71 people were injured, and there were 58 fatalities. The incident holds the title of the second deadliest façade fire on record.
5	Tecom Building, Dubai, UAE	2012	ACP with PE core	Undetermined	2 people sustained minor injuries; falling debris damaged vehicles and caused a pedestrian to suffer minor burn injuries.
6	Lacrosse Tower, Melbourne, Australia	2014	ACP with PE core	A lit cigarette, improperly disposed of, ignited the cladding.	There were 0 casualties, and all 400 occupants were evacuated safely due to the activation of the high-pressure water sprinkler system.
7	The Marina Torch,Dubai, UAE	2015 & 2017	ACP. Core of ACPwas undisclosed	A lit cigarette or coal from a shisha, left unattended on the balcony, ignited the cladding.	There were 0 casualties
8	Address Downtown Dubai Hotel, Dubai, UAE	2016	ACP with PE core	A short circuit in the floodlights installed on the external façade between the 14th and 15th floors triggered the incident.	15 injured
9	Grenfell Tower,North Kensington, West London, United Kingdom	2017	ACP with PE core	The fire was traced to a faulty refrigeration unit located on the fourth floor. Despite the swift response from emergency authorities, the blaze had already spread throughout the entire building, trapping a significant number of occupants.	72 people perished, and the number of injuries remains unreported. It holds the title of the deadliest façade-related fire.
10	Employees Provident Fund (EPF) Building, Petaling Jaya,	2018	ACP with PE core	Sparks generated during maintenance work on the façade, combined with hot weather conditions, resulted in the rapid spread	There were 0 casualties, and 527 employees and

	Selangor, Malaysia			of flames.	customers were evacuated in time.
11	Neo200, Melbourne, Australia	2019	ACP with PE core	A lit cigarette that was improperly disposed of ignited the cladding.	1 injured

METHODOLOGY

The workflow of this study is illustrated in Figure 1. This chart provides an overview of the methodological steps undertaken to conduct the research. The specific steps used to obtain the results through ABAQUS simulation software are presented in Figure 2.

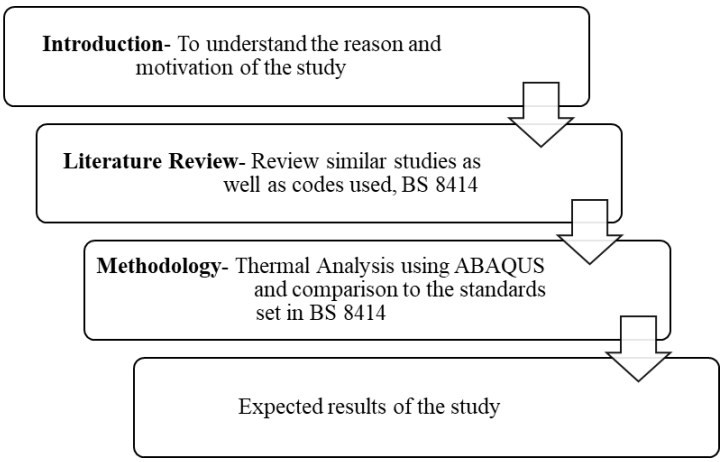

Figure 1: Flow chart of work of study

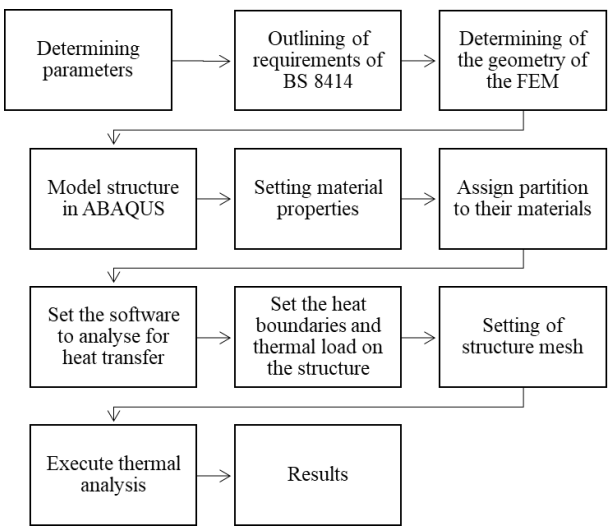

Figure 2: Flow chart on conducting thermal analysis using ABAQUS

Before the thermal analysis could be conducted, the ACP wall model was first developed in ABAQUS. The full-scale façade fire test outlined in BS 8414 Part 1: Fire Performance of External Cladding Systems (2017) was used as a reference for modelling the ACP wall, as it is the industry-standard method for testing flammable façade materials. Figure 3 presents the schematic diagram of the cladded wall mock-up unit used for façade fire testing.

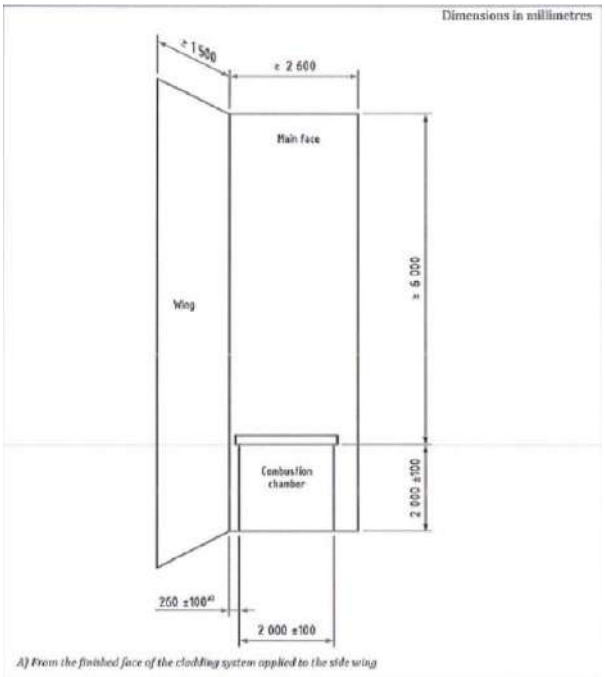

Figure 3: Schematic diagram of external cladding mock-up for fire testing (BS 8414 Part 1: Fire Performance ofExternal Cladding Systems, 2017)

Although the model described in BS 8414 Part 1 (2017) requires a complete façade system to be constructed, this study focused solely on modelling the cladding wall using aluminium composite panels (ACP). This is because the objective was to evaluate the performance of the ACP material in isolation. Furthermore, it was found that ABAQUS software is unable to accurately model the façade wall with all its intricate components and assemblies. Due to the various materials used in ACP production, a typical configuration was selected consisting of two 1 mm thick aluminium sheets and a 3 mm thick polymer core. The different ACP combinations used in the wall modelling, along with the thermal conductivity values of each material, are presented in Table 5.

Table 5: ACP configuration used for software modelling

Set	Aluminium Alloy	Thermal Conductivity (W/mºC)	Polymer Core	Thermal Conductivity (W/mºC)
A	3000 series	171	PE (LD)	0.33
B	3000 series		PE (HD)	0.45
C	3000 series		FR	0.5
D	5000 series	200	PE (LD)	0.33
E	5000 series		PE (HD)	0.45
F	5000 series		FR	0.5

Once all sets of ACP were modelled and partitioned in ABAQUS according to Figure 3, the material properties were defined and assigned to the cladding wall. After assigning the material properties, the analysis settings were configured, and expected outcomes were established to obtain the necessary data for this study. Next, the boundary conditions and thermal load on the ACP wall were applied. For the boundary condition, a room temperature of 20ºC was used, in line with BS 8414 Part 1 (2017), which specifies that room temperature prior to a full-scale test should fall within the range of 15–20ºC. Regarding the thermal load, since the combustion source in the full-scale test is a burning wooden crib, a thermal load of 5000 W/m² was applied, as referenced by Xu et al. (2007). Following the assignment of loads and boundary conditions, the model was meshed with a global mesh size of 0.00625. Once the meshing process was completed, thermal analysis was carried out, and the results were extracted and analysed accordingly.

ANALYSIS AND DISCUSSION

Results Obtained through the Thermal Analysis using ABAQUS

Once the data had been extracted from the point of heat load application to the topmost section of the ACP wall by selecting the relevant nodes it was tabulated for each ACP set, as shown in Figure 4. This data was also visualized using heat maps, providing a clear representation of temperature distribution across the wall, as illustrated in Figure 4 below.

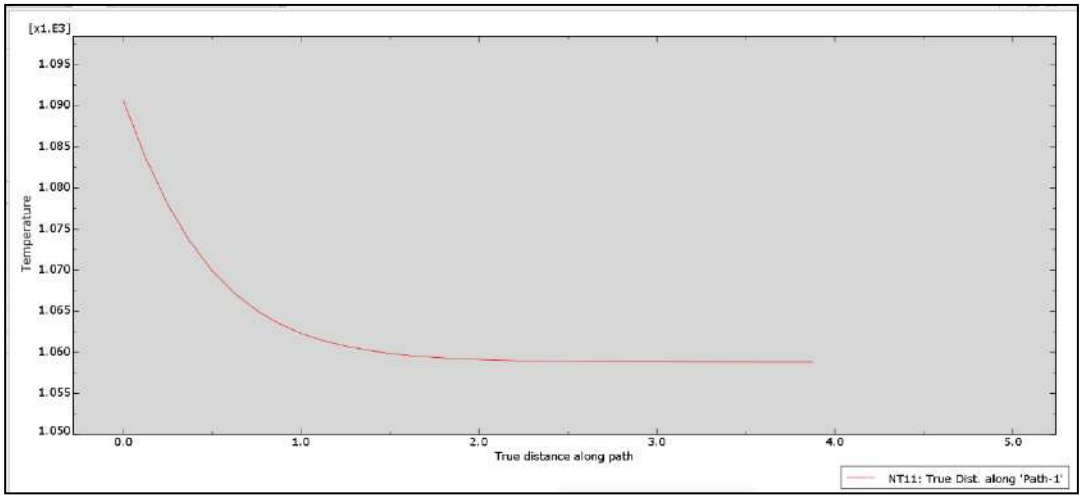

Figure 4: Temperature versus distance from point of impact of Set A ACP

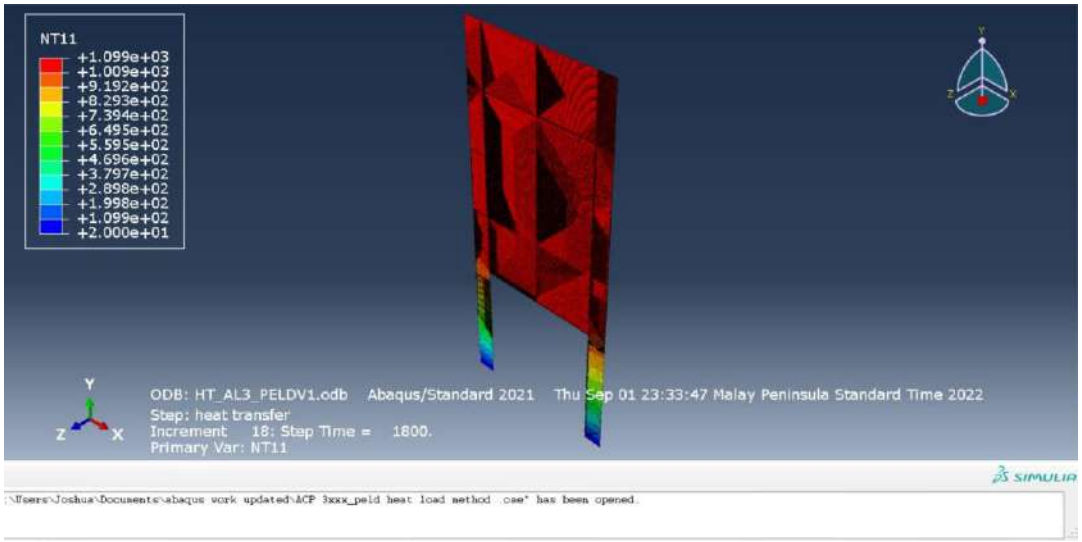

Figure 5: Heat Map of Set A ACP wall

This analysis was conducted at the conclusion of the 30-minute thermal simulation. The data from each table was then condensed into Table 5 by extracting the temperature value of the topmost node. This step was taken to align with the guidelines outlined in BS 8414 Part 1 (2017), which require assessing whether the temperature at the topmost thermocouple, in this case the node exceeds 600˚C at the 30-minute mark. Exceeding this threshold indicates a failure in material safety compliance.

Table 6: Temperature recorded at the topmost section of each set of ACP wall after 30 minutes of thermal load.

Set	Temperature at 6m at t=1800s (˚C)
A	1058.80
B	1058.79

C	1057.71
D	908.541
E	907.744
F	907.412

As shown in Table 6, the ACP in Set F, which is modelled using 5000 series aluminium and an FR core, performs the best among the six sets. However, the temperature recorded at the topmost section of the ACP wall exceeds the 600°C threshold specified in BS 8414 Part 1 (2017). In fact, none of the six ACP sets, regardless of material composition, meet the requirements outlined in BS 8414 Part 1 (2017). When comparing the two aluminium grades, the results indicate that the 5000 series aluminium outperforms the 3000 series across all tested sets. Regardless of the core material paired with it, ACPs using the 5000 series consistently show better thermal performance. For instance, comparing the best-performing 3000 series set (Set C) with the lowest-performing 5000 series set (Set D), Set D still recorded a temperature 141.559°C lower after 30 minutes of exposure to thermal load.

Regarding core material, the FR core clearly demonstrates the best performance, irrespective of the aluminium grade used. This is evident from the fact that in both the 3000 and 5000 series sets, the ACPs with FR cores Set C and Set F, respectively recorded the lowest temperatures. However, temperature differences between core types within the same aluminium grade are relatively marginal, suggesting that the aluminium grade has a more significant impact on thermal performance than the core type.

Types of ACP Used in Current Construction Projects

To identify the types of ACP cladding currently employed in the façade industry, a consultation was conducted with Pintar Jaya (M) Sdn Bhd, a façade engineering consultancy. The company provided detailed information on the types of ACP panels used in three ongoing projects for which they are responsible for both the design and installation of façade components. The list of these projects, including their current status and the type of ACP cladding used, is presented in Table 7 below.

Table 7: Current projects and the types of ACP panels used as provided by Pintar Jaya (M) Sdn Bhd

Name of Project	**Status of Project**	**Type of ACP Panel**
Sunway South Quay CP2, Bandar Sunway, Subang Jaya	Under construction	Brand of ACP has yet to be determined but has been decided to be an FR core with either 3000 or 5000 series aluminium
Pavilion Damansara Heights (Parcel II), Kuala Lumpur	Under construction	Alpolic FR ACP 3000 series
IOI City Mall, Putrajaya (Phase II)	Completed (August 2022)	Alcopla FR ACP 3000 series

As shown in Table 4.7, all three projects prioritize the use of FR (Fire-Retardant) cores over the grade of aluminium. This practice aligns with the updated guidelines issued by BOMBA Malaysia, specifically the Performance Criteria for External Cladding System in Malaysia (FPST/DOC/14-1, Version 1:2019), developed in response to the 2018 EPF building fire (Performance Criteria for External Cladding System in Malaysia FPST/DOC/14-1, 2019). According to the guideline, the use of PE (both LD and HD) cores in external and internal façades is restricted to instances where the ACP system does not exceed 18 meters above platform level. Additionally, PE cores are permitted for internal applications that are not integrated with the primary façade structure. The guideline further mandates that ACP panels installed in systems exceeding 18 meters in height must incorporate fire

barriers and utilize FR cores to ensure enhanced fire safety.

Although the newly implemented standards introduced by the relevant authorities effectively mitigate façade fire risks in new constructions by establishing enhanced safety requirements, they do not extend to existing buildings already fitted with aluminium composite panels (ACP) containing polyethylene (PE) cores. This oversight poses both safety and economic challenges. In relatively new buildings, the premature replacement of ACP panels imposes a substantial financial burden, as building owners may be unwilling to undertake costly upgrades shortly after project completion. Nonetheless, retrofitting may still be a feasible option for these newer structures, given that their building systems remain in good condition and would likely require only minor adjustments to existing fixtures. In contrast, older buildings may demand more extensive and costly renovations to comply with current fire safety standards, making retrofitting less economically viable.

CONCLUSION AND RECOMMENDATION

A total of six different combinations of aluminium sheets and polyethylene (PE) cores were modelled in ABAQUS to represent six types of aluminium composite panel (ACP) wall assemblies. Following a 30-minute thermal simulation, the results indicated that none of the assemblies met the performance criteria outlined in BS 8414 Part 1 (2017). This failure is primarily attributed to the material being assessed in isolation, rather than as part of a complete façade system. This limitation arises from ABAQUS's inability to simulate complex assembly components, such as insulation panels, intumescent coatings, brackets, and fire barriers, elements that are crucial for fire compartmentalisation within ACP systems. Fire compartmentalisation at each level of an ACP-cladded wall plays a vital role in delaying vertical fire spread, thereby reducing the rate of heat transfer from the source to the uppermost parts of the wall (Jensen, 2013).

Moreover, the software's limited capacity to model realistic fire dynamics may have contributed to the failure. In ABAQUS, heat is applied uniformly as a thermal load across the material, which does not reflect the erratic and uneven spread of actual fire behaviour over time. Additionally, data obtained from Pintar Jaya (M) Sdn Bhd confirms that current façade construction projects utilize fire-retardant (FR) cored ACP, which consistently outperforms other ACP variants, regardless of aluminium grade. This practice aligns with guidelines set by BOMBA Malaysia in response to the 2018 Employees Provident Fund (EPF) building fire incident. However, the updated BOMBA guidelines do not specify any directives or policies concerning the replacement of non-compliant ACP cladding on existing structures.

As demonstrated by the simulation results, ACP panels should not be installed as standalone materials, but must be paired with fire-protective components such as intumescent materials, insulation, and fire barriers. This was evidenced in a full-scale test conducted by Façade Resources Sdn Bhd, where an ACP wall integrated with their proprietary fire barrier, Façade Shield™, was tested under the supervision of SIRIM QAS International Sdn Bhd. After 30 minutes of fire exposure, the thermocouple at the topmost level of the wall recorded a peak temperature of only 320°C, which is 280°C below the maximum limit stipulated in BS 8414 Part 1 (2017). This clearly demonstrates that incorporating fire-retardant components significantly improves the fire resistance and safety performance of ACP cladding systems.

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