"The Cement Age": Material Technology, Industry and Infrastructure in India c. 1830-1950.

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A Note on Terminology

The term ‘cement’ carries different meanings depending on the temporal and spatial location under discussion. In the first chapter of this dissertation, which studies the nineteenth century, the use of the term ‘cement’ indicates a ‘cementitious material’ in general. In the second and third chapters whose temporal focus is on the twentieth century by which time Portland Cement had become most prominent, the term ‘cement’ refers to this industrially produced artificial variety, for the sake of ease and consistency with archival sources. Where particular forms of cement are referred to, all chapters use appropriate markers of its variety for clarity. References to all forms and technical varieties of cement and concrete are supplemented with in-text or footnoted explanations throughout the work. Lastly, since cement is the most important ingredient of concrete, when talking about cement this dissertation is also referring to concrete by implication, and it uses these terms interchangeably in some contexts.

Introduction

On a sunlit morning sometime in the early twentieth century, the celebrated British architect Robert Chisholm travelled to the Taj Mahal to see the famed monument in person. Standing at the entrance, he took in the unnatural effect of this “translucent visionary object” made of white marble. From afar, he noticed how everything below the parapet “sparkled in the brilliant sunshine, suggesting tones of crimson, citron, green, and orange” whereas everything above it appeared “cold and lifeless”: the shadows of the roof colder, the shade of the great dome grey. As he walked toward the platform, he swiftly realized that “the roof, which was doubtless also intended to be of white marble, was covered with that dullest of all dull but useful materials, Portland cement - a deep-toned green-grey!”[1]

It is this “dull but useful” material that we know today plainly as ‘cement’. Developed in the 1840s by a British bricklayer, Portland Cement and its unique grey hue had spread quickly across the world. Its resistance to water in particular, occasioned its increasing use in weirs, harbours, lighthouses, bridges and other hydraulic engineering projects in the nineteenth century. As the key ingredient in concrete, its application took on novel forms as newer construction technologies like ferro-concrete and reinforced concrete were popularized from the late nineteenth century onwards. In 1874, the material found its way even to the roof of the Taj Mahal when Agra’s Executive Engineer Mr. Alexander planned to repair and leak-proof the structure by rendering the main dome with Portland Cement, thus creating the “jarring note” that interrupted for Chisholm the “harmonious” intention of the original plan.[2]

Over the course of the twentieth century, Portland Cement continued to monopolize the global built environment. The pliability of the material allowed for its use in contexts ranging from small objects such as pots and sculptures, to lamp posts, pavements, water-tanks, roads and houses as well as larger and more complicated structures like ships, multi-storeyed buildings and multi-purpose dams - not to mention its uncountable presence as patches of repair-work and appendages across our contemporary urban and rural landscapes. As the key ingredient of

[1] Robert F. Chisholm, “The Taj Mahal, Agra, and its Relations to Indian Architecture,” *Journal of the Royal Society of Arts* 59, no. 3033 (1911): p. 171. Chisholm was the architect of the famous 'Indo-Saracenic' structures of Madras and Baroda, including the Presidency College, Chennai, the senate buildings of the University of Madras, the Laxmi Vilas Palace in Baroda and the Napier Museum in Trivandrum.
[2] M.S Vats, “Repairs to the Taj Mahal,” *Ancient India: Bulletin of the Archaeological Survey of India,* no.1 (1946): p. 6.

concrete technology, there is perhaps no other material as ubiquitous and integral to contemporary built environments as Portland Cement.

Yet, as this thesis will elaborate, cement had always carried multiple identities across time, owing to material properties which were contingent on locales, raw materials and the nature of use. Apart from generic lime mortar, cementitious materials like *tufa, chunam* or *kunkur* had been widely in use in various parts of South Asia for centuries. Even in the nineteenth century, suffixes such as 'Pozzolana' 'Roman', 'Parker', 'Margohi', 'Medina', 'Magnesia' or 'Zumaya' based on persons or locations tended to accompany the word 'cement'. In addition to these, other categorizations of cement into hydraulic and non-hydraulic, or natural and artificial, meant that even as late as the early twentieth century, the word 'cement' could have brought to mind no particular material but rather the generic sense of a binding material. In fact, Portland Cement, when it was first developed, was called so for no other reason than its similarity in colour to Portland Stone which was found in Dorset, England.[3] However, by the late nineteenth century, it had assumed a formulaic, homogenized, singularized and industrialized form which was distinct from all other cementitious materials.

This transition from polysemic, plural cements to Portland Cement went hand in hand with other historical developments in the nineteenth and twentieth-century engineering profession and construction economy, such as the setting up of standards and specifications, quality testing, institutionalization of knowledge about construction materials and technologies, as well as the professionalization of labour communities. By the early twentieth century, Portland Cement had come to be championed as *the* material of modernity and progress by industrialists and technical professionals alike. After the Stone Age, the Bronze Age and the Iron Age, they declared the arrival of 'the Cement Age', an unprecedented chapter in their narrative of the history of civilization.[4] The objective of this thesis is to critically examine this 'Cement Age' - its multi-vectored past, its historically manufactured being, and its occupation of the imaginations of divergent futures.

The history of this 'Cement Age' was always was marked by hybridity, and shaped by local socio-cultural, geographic and climatic conditions, labour practices, and notions of

[3] Portland Stone is a type of limestone formation of the late Jurassic epoch, which was quarried on the Isle of Portland and extensively used as a building stone in the British Isles.
[4] This phrase borrows from the title of a magazine published from New York since 1904: 'Cement Age'. Later adopting the more inclusive name 'Concrete-Cement Age', this magazine was dedicated to charting the uses of these materials across the globe. References to 'the concrete age' were also plenty in the publications of this period.

appropriateness. Indeed, Portland Cement was not the only cement used for the repair and reconstruction of the Taj Mahal, though it stood out to Chisholm as incongruous. In 1810, a coloured *chunam* was used to replace the inlaid stones, albeit unsuccessfully. Much later in 1936, even after Portland Cement had become popular and industrially manufactured in South Asia, the Archaeological Survey of India proposed the use of a more suitable special hydraulic lime mortar for repairs and plastering.[5] Many early attempts to use Portland Cement in engineering projects, further, resulted in mixed-structures of cement-concrete and older forms of rubble masonry or *surkhi* mortar, for instance in the Mettur Dam built on the Cauvery river in the 1920s. Some attempts by industrialists and engineers in this period to completely substitute other materials like mud, clay or lime with Portland Cement met with failure, for instance in the materialization of rural infrastructures and roadways. In sum, the total domination of the built environment that the early advocates of modern cement desired, never manifested as they planned.

This contrast between the twentieth-century rhetoric that emphasized the 'universality' of modern artificial cement, and the immensely variant nature of cement and its uses across time, regions and structures is a duality which any work on the history of this material must begin by acknowledging. This dichotomy is also what prompts one to look towards a long and diffused history of experiments, accidents, failures, exchanges and debates surrounding cement. To this study, therefore, cement is inherently plural.

Historicizing Cement

In 1930, an article proposing to outline the 'history of cement' began thus:

> The romance that lies beneath familiar objects is so prone to be lost sight of merely by reason of such familiarity that to enquire into the origin of some well-known product is almost an adventure in itself.[6]

[5] Vats, *op. cit.,* p.5. As recently as 2009, the ASI removed a million tons of cement-concrete from the roof of Humayun’s Tomb, which had been laid by the British in the 1920s to prevent water seepage, and cemented its dome with lime mortar. See: Richi Verma, “At Humayun's tomb, weight is off,” *Times of India,* 9 July 2009.
[6] “The History of Cement: A Few Facts,” *Times of India,* 21 August 1930, p. 15.

A century after the anonymous author articulated the difficulty of looking beneath the surface of the familiar, our concerns remain much alike. How can we explore the pasts concealed by the familiar grey surface of modern Portland Cement we see around us today?

The majority of explorations into the history and use of cement by academic scholarship have been conducted by architectural and construction historians. Consider for instance, the handful of articles on cement and concrete published in the journal *Construction History* since the start of its publication in 1983. They largely focus on the choices, uses and transitions in the structural use of these materials, frequently focusing on particular buildings. What is considered 'historical' in these discussions appear either to be details of the structural evolution of buildings and designs over time, or merely a record of the instances of the use of these materials within a chronological bracket. Their inclination, for the most part, has been to describe design elements or techniques and their use in isolation from other factors. This method ultimately disembeds the material from the socio-economic and cultural contexts which are essential to its historicization. This also means that many of the works on cement and concrete which adopt the frameworks of 'construction history' are blind to the operations of power structures that shape the built environment, even as they focus on buildings and personas embedded in contexts of colonial rule.[7]

Another dominant tendency of the writings on cement and concrete has been to focus on individual architects of import. As Stuart Tappin argues, crucial transformations in construction materials are often understudied due to both the ubiquitous and non-exotic appearance of most cement buildings, as well as the anonymity of the architects working with cement in many cases.[8] This is perhaps why prominent architects and their works receive

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[7] These observations are derived from a meta-analysis of the papers published in this journal - a pioneering platform in its titular domain - between the start of its publication in 1983 and 2017. The material aspects of cement and concrete are explored in these papers through studies on the re-discovery of Roman Cement, the circulation of Pozzolana in Baroque Croatia, the early use of reinforced concrete in India, the history of the use and production of cement tiles in Brazil or the production and use of hollow concrete blocks in New Zealand in the early twentieth century. As far as the structural use of concrete is concerned, works range from discussions on the choice between steel and reinforced concrete in highway bridge design in early twentieth century Washington to the historical influences on the use of cement in Mexican domestic construction. Other topics considered include the interfaces between architecture, engineering and technology in concrete construction in Belgium, early concrete architecture in Estonia and the concrete shells in its seaplane hangars, the use of concrete in British canal locks in the nineteenth century, the Concrete Air Raid Shelters in mid-twentieth century Britain, the development of reinforced concrete shells in Mexico in the first half of the twentieth century and earthquake resistant construction techniques using alternatives to reinforced concrete in Italy between 1880 and 1910. Patricia Cusack's papers in these issues reveal how architects were always considered the key 'agents of change' in the use of cement and concrete. For example, see: Patricia Cusack, "Agents of Change: Hennebique, Mouchel and Ferroconcrete in Britain, 1897-1908," *Construction History* 3 (1987).

[8] Stuart Tappin, "The Early Use of Reinforced Concrete in India," *Construction History* 18 (2002): p. 79.

more attention in comparison to the 'unremarkable' elements of the built environment. Even in one of the most imaginative historical works on concrete as a material medium, architectural historian Adrian Forty focuses on architects and the design of buildings, because he holds that "architects have paid more attention to the interpretation of concrete as a medium of culture than any other occupation."[9] This premise leads Forty to mistake the values that cement and concrete came to embody over time, particularly for architects, as its historical being.

Notwithstanding, Forty's work signals an array of important themes. He muses over the impassive and negative associations that the material has carried over time, pointing out how figures of speech in many languages reflect the way concrete has been regarded as a "dumb or stupid material, more associated with death than life."[10] He argues how concrete has been described as a "mongrel" material by architect Frank Lloyd Wright himself, who had pioneered the use of reinforced concrete and concrete blocks in houses.[11] Forty also points to the conception of concrete as an ahistorical material by some architects in the twentieth century. As it came to be increasingly associated with the project of modernity, concrete was tied also to critiques of the spatial practices that produced the 'alienation' of modern city life. As Lefebvre wrote in 1960 about a new town and its concrete buildings: "Here I cannot read the centuries, nor time, nor the past, nor what is possible."[12] In the latter decades of the twentieth century, reinforced Concrete- cheaper and more compliant to unskilled work- was redefined as one of the 'new technologies of poverty', argues Forty: "In overall quantity consumed, its use by self-builders in poor countries probably exceeds all other applications."[13] Though it had been considered a marker for the optics and metrics of development across the world in the twentieth century, "seen from the developed world [today], part of what makes reinforced concrete disagreeable is precisely its poverty, its association with the slums of Mumbai or Mexico City", he writes.[14]

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9 Adrian Forty, *Concrete and Culture: A Material History* (London: Reaktion Books: 2016), p. 9.
10 *Ibid.* In German, for instance, "Beton-Fraktion" indicates a stubborn political group, "Beton Kopf" or 'concrete head' refers to a reactionary political opponent. Similarly, in French, the street slang "laisse beton" means 'drop dead'. Indeed, the very word *beton* (the French term for concrete), came from *betum*, which means a mass of rubbish on the ground. Forty also points out other contemporary cultural perceptions of concrete, as for instance, in Kate Grenville's novel *The Idea of Perfection*, where the main character's boring qualities are communicated through the fact that he is a concrete engineer.
11 *Ibid.,* p. 10. Concrete is made by mixing cement, sand and stone aggregates, hence this label.
12 As quoted in: Adrian Forty, "Concrete and Memory," in *Urban Memory: History and Amnesia in the Modern City*, ed. Mark Crinson (London: Routledge, 2005), p.75
13 Forty, *op. cit.*, *Concrete and Culture*, p. 40.
14 *Ibid.,* p. 41.

Though such value associations are themselves historically shaped, one must look further than a history of attitudes in order to observe the historical channels and trajectories of cement and concrete. It is equally important to examine the larger transformations in building materials and technologies because, as systems of rules, these new materials have shaped the formation of social spaces and the evolution of technical expertise and related hierarchies of knowledge and labour.

In doing so, one must move beyond both the myopic focus on particular buildings and structural changes, as well as architects and their perceptions of cement and concrete. Isolated works have attempted to this by considering other actors in the history of cement and concrete. John Weiler, in the 1980s, considered the role of British military engineers - whom he called 'army architects' - in the development of building technologies, though using the now obsolete framework of ‘technology transfer’.[15] The important connections between military engineers, masons and hydraulic cement has been also explored by Chandra Mukherji in the context of seventeenth-century France, by exploring the material and textual memories of *pozzolan* hydraulic cement of Roman times, its perpetuation as tacit knowledge and artisanal epistemologies, and how it converged with the formal knowledge of military engineers in the infrastructural projects of the seventeenth century.[16] More recent historiographical developments have signalled new possibilities of historicizing the role of engineering in the evolution of cement-concrete technologies. For example, Amy Slaton, in her work on reinforced concrete and the modernization of American building in the early twentieth-century, traces the role played by engineering education and the development of testing in creating a new division of labour in construction.[17] A number of works have also focused on other agents in the institutional and industrial contexts of the evolution of cement as a material.[18] For example, Humphrey Ko writes a history of China's political economy and

[15] John Weiler, *Army Architects: The Royal Engineers and the Development of Building Technology in the Nineteenth Century* (University of York, 1987). Also see: John Weiler, “Colonial Connections: Royal Engineers and Building Technology Transfer in the Nineteenth Century,” *Construction History* 12 (1996): pp. 3-18.
[16] Chandra Mukerji, “Tacit Knowledge and Classical Technique in Seventeenth-Century France: Hydraulic Cement as a Living Practice among Masons and Military Engineers,” *Technology and Culture* 47, no. 4 (2006): pp. 713-33.
[17] Amy Slaton, *Reinforced Concrete and the Modernization of American Building: 1900-1930* (Baltimore: Johns Hopkins University Press, 2001).
[18] For instance, the legacy of firms like Concrete Publications Ltd. and the Cement and Concrete Association in Britain, or the interaction between the German Committee for Reinforced Concrete and the concrete industry in Germany between 1907 and 1945 have been studied. See: Edwin Trout, “Concrete Publications Ltd and Its Legacy to the Concrete Industry,” *Construction History* 19 (2003): pp. 65-86; and Edwin Trout, “The Deutscher Ausschuβ Für Eisenbeton (German Committee for Reinforced Concrete) 1907-1945. Part 1: Before World War I,” *Construction History* 29, no. 1 (2014): pp. 51-73.

legal structures in the nineteenth and twentieth century, through an exploration of the particularities of the emergent cement industry in the region.[19]

The use of concrete in public housing schemes has also been a subject of some attention.[20] Most recently, Kataryna Malaia has attempted to contextualize the use of pre-fabricated concrete panels for urban-housing construction in the Soviet Union between the 1950s and 1960s, against the larger patterns of industrial production, the institutional and bureaucratic mechanisms of the planned Soviet economy, as well as its ideological moorings. She argues that urban residential architecture in concrete was far from shaped by individual designers, but rather these industrial and socio-political forces.[21] New perspectives on concrete in housing construction have also emerged from ethnographic studies, such as Krisztina Fehérváry's exploration of the politics surrounding materials in socialist Hungary in the latter half of the twentieth century. Fehérváry suggests that concrete captured a human-object relationship along with the social and cultural practices woven around it in the country's everyday life. By virtue of its presence in the architecture of domestic spaces, concrete acted as a material intermediary between subjects and the state, she argues.[22] Yet another analysis has been put forward by David Morton who looks at urban housing in post-1940s Mozambique through concrete and the aspirations associated with it. Through concrete construction, Morton argues, house-builders of Maputo defined the meanings and forms of governance.[23]

Similar studies focusing on aspects of technology, industry, technical expertise, infrastructural applications or affective politics of concrete and cement in South Asia are yet to emerge.

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[19] Humphrey Ko, *Making of the Modern Chinese State: Cement, Legal Personality and Industry* (Singapore: Springer Verlag, 2018).

[20] An early case-study in *Construction History* briefly documented the use of reinforced concrete at a public housing estate in Lisbon. More recently, a study has discussed the use of pre-fabricated concrete panels for public housing by Marcel Breuer and Jean Barets in Bayonne, France. However, as discussed earlier, these papers remain focused on *recording* the use of concrete in structures rather than *historicizing* it. See: Alexandra Alegre and Teresa Heitor, "Flexibility in the First Generation of Reinforced Concrete Housing: A Public Housing Estate in Lisbon," *Construction History* 20 (2004): pp. 85-93; and Lauren Etxepare, Eneko J. Uranga, and Naiara Zuazua-Guisasola, "Marcel Breuer and Jean Barets in Bayonne (1964-68): The Use of Architectural Precast Concrete Panels in Large Public Housing Schemes," *Construction History* 30, no. 1 (2015): pp. 109-26.

[21] Kataryna Malaia, "A Unit of Homemaking: The Prefabricated Panel and Domestic Architecture in the Late Soviet Union," *Architectural Histories 8,* No.1 (2020).

[22] Krisztina Fehérváry, *Politics in Color and Concrete: Socialist Materialities and the Middle Class in Hungary* (Bloomington: Indiana University Press, 2013).

[23] David Morton, *Age of Concrete: Housing and the Shape of Aspiration in the Capital of Mozambique* (Ohio: Ohio University Press, 2019).

In the South Asian context, cement has most frequently been studied as a commodity, with a disproportionate focus on the period after 1947. These work have largely tended to hone in on aspects like industrial policy, capacity, efficiency, competition, locational patterns, financial performance, and the impact of governmental price control post-independence.[24] The main exceptions to this trend are Amiya Kumar Bagchi's brief analysis of the inter-war cement industry in his larger work on the evolution of private investment in India, as well as Kumar Bar Das' historical profile of the economic trajectory of the Indian cement industry between the 1910s and 1980s.[25] Beyond such analyses of industrial history, the focus has remained on specific architects or buildings in line with the larger drift discussed above. For instance, Kathleen James-Chakraborty studies reinforced concrete in Louis Kahn's work in Dhaka with an eye on his aesthetic choices and location vis-à-vis conventional modernist architecture.[26]

An interesting exception to these dominant trends, is Joyce Flueckiger's recent article on the materiality of cement statues of Ravan in Chhattisgarh, and its influence on the challenges to the dominant narratives of Ramayana in this region. To Flueckiger, the material agency of these statues renders Ravan more visible than what his story allows in verbal narratives.[27] Clearly, cement and concrete as materials offer a multitude of historical narratives on South Asia which are yet to be told.

[24] See for instance: A. K Agarwal and V. K. Agarwal. *Cement Industry in India: a Critical Study of Capacity Utilisation* (New Delhi: Commonwealth Publishers, 1990); Madhu Bala, *Cement Industry in India: Policy, Structures and Performance* (Delhi: Shipra Publications, 2003); Mahesh V. Joshi and Girish Mehta. *Globalization and Indian Cement Industry* (New Delhi: Adhyayan Publishers & Distributors, 2006); and Vishnu Podder, *Cement Industry in India*. (Bihar: Rohtas Industries, 1962).

[25] Amiya Kumar Bagchi, *Private Investment in India, 1900-1939* (Cambridge: Cambridge University Press, 2008). See the chapter "The Cement Industry". For the latter analysis, see: Kumar Bar Das, *Cement Industry of India* (New Delhi: Ashish Publishing House, 1987), pp. 29-53.

[26] Kathleen James-Chakraborty, "Reinforced concrete in Louis Kahn's National Assembly, Dhaka: Modernity and Modernism in Bangladeshi Architecture," *Frontiers of Architectural Research* 3 (2014): pp. 81-88.

[27] Joyce Burkhalter Flueckiger, "Standing in cement: possibilities created by Ravan on the Chattisgarhi plains," *South Asian History and Culture* 8 (2017): pp. 461-477. Curt Gambetta has also made a step in the direction of studying the materiality of cement and its movements, blending historical and ethnographic approaches to examine the circulation of building materials and the technologies of infrastructure in Bangalore. See: Curt Gambetta, "Material Movement: Cement and the Globalization of Material Technologies," *Scapegoat,* no. 2, (2011): pp. 26-28.

Approaching Cement: Material, Technology and Infrastructure

In historicizing cement, this thesis draws upon the interconnected historiographical fields of material history, history of science and technology, and infrastructural history.

What does it mean to study cement as a material? The methodological implications of studying materiality have been explored, in recent decades, by the growing literature on the significance of natural and artificial material forces to social structures and the operations of power. This literature has also examined the impact of non-human agencies on quotidian life.[28] While material histories have conventionally tended to focus on artefacts, objects or commodities due to its roots in material-culture studies, a focus on the materiality of matter has marked many recent studies. Influenced by Latourian reimaginations of agency, networks and social assemblages, as well as the project of New Materialism to lend vitality to matter, these studies engage with materiality beyond its mediation of the social and the cultural as 'objects'.[29]

Thus, in comparison to Arjun Appadurai's attribution of 'social lives' to things, many material histories now attempt to turn away from the distinctions between the natural and the social, and the human and the non-human, which are divisions which presume an essential difference between the material and the immaterial.[30] In fact, Appadurai himself later referred to the "conceit" of the idea of objects having social lives, and remarked that "persons and things are not radically distinct categories,…the transactions that surround things are invested with the properties of social relations."[31]

[28] See Tony Bennett and Patrick Joyce, *Material Powers: Cultural Studies, History and the Material Turn*, (Hoboken: Taylor and Francis, 2013), for a discussion on the 'material turn'. Also see: Chandra Mukherji, "The Material Turn" in Stephen Michael Kosslyn and Robert A. Scott ed., *Emerging Trends in the Social and Behavioral Sciences: An Interdisciplinary, Searchable, and Linkable Resource* (Hoboken, NJ: John Wiley & Sons, 2015), pp.1-13.
[29] Partha Chatterjee, Tapati Guha-Thakurta and Bodhisattva Kar, *New Cultural Histories of India: Materiality and Practices* (New Delhi: Oxford University Press, 2014).
[30] Daniel Miller, "Materiality: An Introduction", in Daniel Miller ed., *Materiality* (Durham: Duke University Press, 2005). See Christopher Pinney's essay in this volume for his work on Hindu images from the late nineteenth century, which, attempts to use images not as illustrations of something already established elsewhere, but rather asks whether it is possible to envisage history as in part determined by struggles occurring at the level of the visual, or the material, by studying chromolithographic presses as experimental zones. *Ibid,* p. 257-272. Also see: Jane Bennett, *Vibrant matter: a Political Ecology of Things* (Durham, NC: Duke University Press, 2010) and Diane Coole and Samantha Frost, *New Materialisms: Ontology, Agency and Politics* (Durham: Duke University Press, 2010) for theorizations and examples of the 'vitality' of matter.
[31] Arjun Appadurai, "The Thing Itself", *Public Culture* 18*,* No. 1 (2006): p. 15. For Appadurai's earlier conception of the social lives of things, see "Introduction: Commodities and the politics of value" in Arjun Appadurai ed., *The Social Life of Things: Commodities in Cultural Perspectives* (Cambridge: Cambridge University Press, 1986).

This 'material turn' in historiography has influenced many vital studies of the spread of logistical power, governmentality and modern forms of expertise under the aegis of the state, as in the work of Chandra Mukherji, or the implications of paper and filing systems within the colonial and post-colonial bureaucracies explored by Mathew Hull and Patrick Joyce respectively.[32] This thesis, in line with these attempts to reinvigorate the agency of materials, consider cement and its technological being as more than just functional or instrumental objects, but as an agent in the evolution of technological systems in the built environment.

A reimagination of materiality has also offered a new critical approach to conventional industrial histories which have tended to undertheorize 'new materials'. In the recent book *New Materials: Towards a History of Consistency,* a collection of essays edited by Slaton, scholars consider cases of 'novel' industrial materials in the past two centuries ranging from living organisms grown for human food, metallurgical innovations and known metals put to new purposes, to cloth, wood, plastic, minerals, flesh, light, air, and water. Questioning taxonomies such as 'invention' and 'industrial material', the authors of these essays attempt to trace the process of making materials 'new', as well as histories of their technology and commerce in relation to the distribution of risk, security and economic mobility.[33] As Slaton points out in her introduction to the volume, "when some matter is seen to be novel in a particular time and place, defined as a useful material for commerce, or simply delineated as the result of human artifice, a significant set of social enactments has occurred."[34] This study explores how cement was reconfigured as a 'new material' in twentieth century industrial context, as well as one with a longer material past, tracing the transformations from the latter to the former.

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[32] Chandra Mukherji, "Intelligent Uses of Engineering and the Legitimacy of State Power," *Technology and Culture* 44, no. 4 (October 2003): pp. 655-676; Chandra Mukherji, "Material Practices of Domination and Techniques of Western Power," *Theory and Society* 31, no. 1 (2002): pp. 1-31; Chandra Mukherji, "The Territorial State as a Figured World of Power: Strategies, Logistics, and Impersonal Rule," *Sociological Theory* 28, no. 4 (December 2010): pp. 402-424; Also see: Mathew Hull, *Government of Paper the Materiality of Bureaucracy in Urban Pakistan* (Berkeley: University of California Press, 2012); Patrick Joyce, "Filing the Raj: Political Technologies of the Imperial State," In *The State of Freedom: A Social History of the British State since 1800* (Cambridge: Cambridge University Press, 2013), pp. 144-84; See Patrick Joyce and Chandra Mukherji, "State History and Theory Reconfigured", *Theory and Society,* 46 (2017): pp. 1-19, for further discussions on the relationship between material processes and logistical power.

[33] Amy Slaton, ed., *New Materials: Towards a History of Consistency* (Amherst, Massachusetts: Lever Press, 2020). For instance, in this book, Karen Senaga links the 'makeover' of catfish in late-twentieth century United States to the artificially constructed and subjective determinations of flavour, which in turn informed constructions of class and race (pp. 40-73). Other 'new materials' discussed in this book include oranges from the orchards of early-twentieth century Southern California, wooden skyscrapers in contemporary United States, iron in early nineteenth century Quaker asylums, Carbon-Fiber-Reinforced Polymers in the Taiwanese cycling industry, *kansa* utensils in South Asia, etc.

[34] *Ibid.,* p.4.

This thesis also draws from and builds upon the history of science and technology in South Asia. As Shruti Kapila has pointed out, the bulk of the early literature in this field has attempted, though in different ways, to challenge Basalla's three-phased model of 'diffusion' of technology from the metropole to the colony.[35] Questioning this prototype, historians of science and technology in colonial South Asia have relied on the concept of a distinct 'colonial science', marked by coloniality and grounded on the specificities of localities. Roy MacLeod and Deepak Kumar, for example, have argued that science and technology were often delimited by the requirements of the colonial government.[36] Zaheer Baber, similarly, postulated that the "colonial construction of modern science" was determined by colonialism, scientific knowledge and institutions co-producing each other.[37] The literature on colonial science and technology has also emphasized the reinterpretation and translations of 'Western' science in the colony. Pratik Chakrabarti, in this context, explores the subversions and resistances in the process of constituting science.[38] Beyond examinations of 'hybridity', a set of works decentred the model of 'transfer' by examining the discrete traditions that emerged in the colony. Citing the openness and adaptability of pre-colonial scientific and technological traditions in India, David Arnold, for instance, argued for an interactive model.[39] The need to consider the varied nature of exchanges between modern science and traditional forms of knowledge have also been pointed out by S. Irfan Habib and Dhruv Raina.[40]

To argue for the concept of 'contact zones' as sites of production of scientific knowledge, Kapil Raj considers cases such as the collaborations with local informants and artists in seventeenth and eighteenth-century botanical science, or the negotiation of legal experts. In Raj's approach, the 'circulation of knowledge' becomes crucial, whereby localities reinvent themselves through the circulation of objects, skills, ideas and practices across regional and global spaces. Raj

[35] Shruti Kapila, "The Enchantment of Science in India", *Isis* 101, No. 1 (March 2010): pp. 120-132. The essence of Basalla's model has influenced early works on the history of technology in the colonies, such as Daniel Headrick's analysis of 'technology transfer' and the operations of the 'tools of empire'. See: Daniel Headrick, *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940* (New York: Oxford University Press, 1988). For more on the original concept of 'diffusion', see: George Basalla, "The Spread of Western Science," *Science*, New Series 156, no. 3775 (1967): pp. 611-22.

[36] Roy MacLeod and Deepak Kumar ed., *Technology and the Raj: Western Technology and Technical Transfers to India 1700-1947* (New Delhi, Thousand Oaks and London: Sage, 1995). Kumar has also underlined the negotiations between colonial officials and the rigid hierarchies of the colonial system in India. Deepak Kumar, *Science and the Raj, 1857-1905* (Bombay and Oxford: Oxford University Press, 1995).

[37] Zaheer Baber, "Colonizing nature: scientific knowledge, colonial power and the incorporation of India into the modern world-system," *British Journal of Sociology* 52, no. 1 (2001): pp. 37–58.

[38] Pratik Chakrabarti, *Western Science in Modern India: Metropolitan Methods, Colonial Practices* (Delhi: Permanent Black, 2004),

[39] Arnold, *Science, Technology and Medicine in Colonial India (The New Cambridge History of India Vol. III.)* (Cambridge: Cambridge University Press, 2000).

[40] S. Irfan Habib and Dhruv Raina ed. *Social History of Science in Colonial India* (New Delhi: Oxford University Press, 2007).

studies the spaces of circulation where colonial knowledge was formed through reciprocal, albeit asymmetric flows and negotiations. Rather than being a site where European scientific knowledge was applied, he argues, South Asia participated in the constitution of what was to become ‘modern’ science.[41]

A majority of the literature on the history of science and technology in South Asia focuses on the period of the nineteenth century, or before. The handful of writings on the first half of the twentieth century generally scrutinize on the role of science and technology in the discourses of nationalist intellectuals in the process of creating an ‘Indian’ modernity. Gyan Prakash, for example, explores how twentieth century nationalist discourse borrowed colonial policies of ‘technologies of government’. He also examines how Indian elites engaged with ‘Western’ science and renegotiated knowledge and power in constructing an identity for themselves as champions of Indian modernity.[42] Kumar's study, similarly, surveys how the colonial government and nationalists articulated their own versions of modernity.[43]

As Aparajith Ramnath has recently argued, beyond the discourse of Indian elites, attention ought also to be paid to a history of practice and practitioners in this period. The focus on conceptions of modernity as it existed in twentieth century discourses, in other words, must not run the risk of overlooking the gritty and complex process of making technologies. In his work on the engineering profession and its relationship to industry and state in India, therefore, Ramnath attempts to focus on the experiences of practitioners of technology.[44] Other recent works have similarly opened up newer avenues of exploration. David Arnold’s analysis of everyday technologies and machines and Phalkey’s study of nuclear science in practice, are tied together by their attention to the early twentieth century as a period of novel forms of technological transformations.[45] Prakash Kumar’s global *longue durée* history of the

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[41] Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe, 1650-1900* (New York: Palgrave Macmillan, 2007),

[42] Gyan Prakash, *Another Reason: Science and the Imagination of Modern India* (Princeton: Princeton University Press, 1999).

[43] Deepak Kumar, “Reconstructing India: Disunity in the Science and Technology for Development Discourse, 1900-1947,” *Osiris* 15 (2000), pp. 241-257. Pratik Chakrabarti's work also explores the ideas of individual nationalist thinkers. See: Chakrabarti, *Western Science in Modern India, op. cit.*

[44] Aparajith Ramnath, *The Birth of an Indian Profession: Engineers, Industry, and the State, 1900-47* (Delhi: Oxford University Press, 2017).

[45] David Arnold, *Everyday Technology: Machines and the Making of India’s Modernity* (Chicago: University of Chicago Press, 2015) and Jahnavi Phalkey, *Atomic State: Big Science in Twentieth-Century India* (Ranikhet: Permanent Black in association with Ashoka University, 2019).

science of indigo plantations attempts to connect the changing materiality and scientific knowledges of indigo to colonial and industrial forces.[46]

As Phalkey points out,

> We are just barely beginning to explore questions of scientific practice. What did people actually *do*—as opposed to what we think they might have been up to—when they were making what they considered scientific knowledge?...We lack histories of laboratories, scientific instruments and material cultures, academic scientific research, industrial research, funding patterns, political economy, corporations and philanthropy, defense research and military history. A range of institutional, social, political, economic, and cultural contexts have to be studied in order to narrate and interpret the intersecting meanings of failure, success, and everyday lives of science for a people's history of science in India, and that includes, especially, the experiences of its practitioners.[47]

The proposed study attempts to consider some of these questions, by examining the previously underexplored domain of cement and concrete technologies. In exploring the evolution of expertise in material technology from the 1850s to the 1940s, cement and engineers will be considered two agents in a system of technological practice, influencing each other in spaces of knowledge formation, industrial production, and infrastructural application.

A third and related historiographical field this dissertation draws from, is infrastructural history. Histories of the material built environment in South Asia have largely tended to focus on the social production of space, its role in the spread of state control, aspects of governmentality, or the social and cultural interactions of humans with these structures. Manu Goswami, for instance, has analysed the production of a national space in relation to colonial economy through the creation of networks of transport and infrastructure.[48] Further, Ravi Ahuja's work on transport history and built environments, particularly on road-building in colonial Orissa, has redefined the idea of 'infrastructure', interpreting concepts such as 'public works' as materializations of social relations in space. The rhetoric of 'improvement' surrounding infrastructure has also been analysed by him.[49] However, it is important to move beyond understanding this socially produced space as being regulated by colonial policy or state-

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[46] Prakash Kumar, *Indigo Plantations and Science in Colonial India*. (New Delhi: Cambridge University Press, 2013).
[47] Jahnavi Phalkey, "Introduction," *Isis* 104, no. 2 (2013): pp. 335-336.
[48] Manu Goswami, *Producing India: From colonial economy to national space* (Chicago: University of Chicago Press, 2010).
[49] Ravi Ahuja, *Pathways of Empire: Circulation, Public Works and Social Space in Colonial Orissa c. 1780-1914* (Hyderabad: Orient Blackswan, 2009).

decisions alone, and attempt to comprehend the infrastructural built environment as also technological systems that accommodate other agencies.

Histories of infrastructure and public works have also been driven by themes of labour, governance, and the materiality of space.[50] A number of works, in this context, have analysed railway infrastructures. Ian Kerr, for example, discusses railway and road construction as sites where labour circulated, and the effect of these public works on occupational groups.[51] Laura Bear, similarly, studies the persistence of social hierarchies in infrastructural spaces of rail-travel, railway workshops and housing.[52] The ‘space’ of the railways -its carriages, platforms and kitchens- has also been approached as a site of everyday interactions and encounters with technology through colonial governance in the works of Ritika Prasad and Aparajita Mukhpadhyay.[53] In a different vein, Debjani Bhattacharya explores infrastructure through categories of technology, ecology and market governance in her history of the urban space of Calcutta, without granting the state sole agency in determining the influence that public works had on the material space of the city.[54]

The project will contribute to this literature anchored around ‘infrastructure’ as an analytical category. Rather than looking at how the built environment constituted space, or social space, this dissertation will consider how cement and concrete shaped and defined the limits of infrastructural imaginations. It is as interesting, in this context, to look at cement's absences in the built environment, as it is to see its dominating presence.

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[50] For a discussion on the themes explored by infrastructural history, see: Aditya Ramesh and Vidhya Raveendranathan, “Infrastructure and Public Works in Colonial India: Towards a Conceptual History,” *History Compass* (2020).

[51] Ian Kerr, *27 Down: New Departures in Indian Railway Studies* (New Delhi: Orient Longman, 2007) and Ian Kerr, *Engines of Change: the Railroads That Made India* (Hyderabad: Orient Blackswan, 2012).

[52] Laura Bear, “Lines of the nation: Indian railway workers, bureaucracy, and the intimate historical self” In *Cultures of History* (New York: Columbia University Press, 2007).

[53] Ritika Prasad, *Tracks of change: Railways and everyday life in colonial India* (Cambridge: Cambridge University Press, 2016) and Aparajita Mukhopadhyay, *Imperial technology and “native” agency: A social history of railways in Colonial India, 1850-1920* (New York: Routledge, 2018).

[54] Debjani Bhattacharya, *Empire and ecology in the Bengal Delta: The making of Calcutta* (Cambridge: Cambridge University Press, 2018).

Chapters

The study begins by complicating the narrative that cement and concrete were inventions perfected in and diffused from Europe. The first chapter discusses the proliferation of sites across global spaces of engineering and empire, where experiments on multiple forms of cements were conducted in the nineteenth century, ranging from Chatham to Calcutta. The interactions between cementitious materials and colonial engineers were shaped by concerns over the shifting equilibrium between quality, accessibility, cost, scale, efficiency, and aesthetics. This chapter is also a study in how a body of technical literature on cement, replete with narrative elements, was consolidated and circulated in this period.

Against this background of cement's polysemic materiality, the second chapter takes up the story of Portland Cement- the most commonly used artificial cement today. It examines how Portland Cement came to be industrially manufactured and mediated by processes of standardization and codification in early-twentieth century India. It looks at the industrial and technological rhetoric of this 'Cement Age' which endorsed it under labels of modernity and progress, as well as the resistance it faced. In this context, the construction of a technical and unique identity for cement, the processes of codification and testing, standardizing pedagogic practices, and the representations of cement as a 'modern' material, will be discussed.

One of the consequences of recasting cement as a distinctly modern material was the emergence of a construction paradigm founded on the notion of 'expertise'. The final chapter considers three infrastructural contexts in the first half of the twentieth century, to investigate the aspirations, manifestations, and the limits of this paradigm. It explores the construction of the first entirely concrete dam at Mettur by the Madras government in the 1920s, the cement industry's drive to build concrete villages for India's post-war development in the 1940s, and the crusade for concrete roads in India between the 1920s and 1940s. In one way or another, all three projects remained unrealized. These early 'failures' are revelatory of both the hybridity that continued to challenge this new paradigm, and the place which this material came to occupy in conflicting visions of the future. By following the story of cement, thus, this chapter attempts to unpack the evolving relationships between material and human agencies in the process of imagining, engineering, and fabricating our built environment.

Chapter One

Cement in The Empire: Experiments and Narratives in the Nineteenth Century

Addressing a room of military engineers at the Royal Engineers Institute at Chatham in 1898, British civil engineer Alfred Edward Carey prefaced his technical lecture on Portland Cement with what he called "the historical aspect of the question":

> In various developments and advances in scientific work which have been originated during Her Majesty's reign, no one, so far as I am aware, has recalled the fact that the manufacture of Portland cement is practically an art of the Victorian era. Considering the various applications of this material, and the fact that it has enabled works to be carried out which, without it, would have been impossible, or only practicable at an enormously enhanced cost, its inception may certainly be regarded as one of the industrial triumphs of Her Majesty's reign…Portland cement is the product of English intelligence and perseverance.[1]

In attempting to consolidate an identity for cement, and to inextricably link the material, its technological evolution and industrial production to Britain, Carey rewrote the history cement in a way that highlighted this "intelligence and perseverance." He continued, in his lecture, to talk about the "profound and lucid" mind of British civil engineer John Smeaton who "first grasped the true significance of hydraulicity in cements".[2] General Charles William Pasley, the Director of the Royal Military Establishment, and General Andrew Clarke, receive special mention as the subsequent key players in the history of cement technology. The two other names that figure in Carey's narrative of the history of cement, are Joseph Aspdin, a British builder who first took out a patent for Portland Cement in the mid-nineteenth century, and more prominently, Mr. John Grant, an engineer who had "boldly pinned his faith to the reliability of sound Portland cement" since the 1860s and had become an expert on the material.[3]

Carey's was not the only 'technical' discussion on cement and concrete which began with some allusion to the history of the material. Many a paper discussed at the British Institution of Civil

[1] A. E Carey, "The Selection, Testing and Employment of Cement", *Professional Papers of the Corps of Royal Engineers,* Royal Engineers Institute, Vol 24 (1898): p 1. Carey was a member of the British Institution of Civil Engineers who routinely wrote in engineering journals about his experiences with cement and concrete testing and application from the 1890s.
[2] He also acknowledged in passing the contributions of French engineer Vicat who discovered artificial cement in 1817, but with the dismissive caveat that "apparently he got his clue from the researches of Smeaton." *Ibid.,* p. 2.
[3] *Ibid.,* p.3.

Engineers in the early to mid-nineteenth century began with references to military engineer Vitruvius, or Pliny, and Roman methods of construction. Some followed the history into the use of these materials in ancient Greece.[4] Often, French architects and engineers like Philibert Delorme, M. De Cessart, Vicat and Treussart or chemists like Chaptal and Guyton de Morveau found a place in these narratives. Others cast a wider net, one engineer tracing it to "the earliest periods of antiquity…[when] those materials were used in all the cities and public buildings of Egypt, Assyria, Etruria, Greece, Rome, China, India, and South America, long before the Christian era"[5]

However, Carey's lecture signalled a language and rhetoric markedly different from the earlier engineers who wrote on cement. His attempt was not to place Portland Cement in a longer civilizational narrative, but rather to manufacture a history separate from the developments in mainland Europe, and unique to Britain. Cement, at the turn of the century, was thus definitively marked with the concerns and apprehensions of Britain and its geopolitical ambitions and conflicts.[6]

Most commonplace accounts of the history cement and concrete echo this narrative that Carey had manufactured in 1898. After detailing the use of cement across civilizations of antiquity, and in eighteenth century Europe, they leap to the industrial and engineering developments in nineteenth century Britain, where the birth of modern hydraulic cements is then unequivocally placed.[7]

This chapter is an attempt to decentre this story - fashioned in the late nineteenth century and reinforced by engineers and industrialists in the subsequent decades - of modern hydraulic cements.

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[4] *Minutes of Proceedings of the Institution of Civil Engineers,* Institution of Civil Engineers*,* Vol I (1837-41): p. 3.
[5] *Minutes of Proceedings of the Institution of Civil Engineers*, ICE, Vol XVI (1856-57): p. 423.
[6] This is also why Carey dismisses the work of the French engineers and architects, and why he expressed anxieties over losing authority over the material: "As has been the case in other fields, the Germans, for a time, beat us on our ground, making a more finely ground and constant product. England is now, however, fast regaining the lead, which she should never have lost." Carey, *op. cit.,* p. 3.
[7] Consider, for instance, a common source of reference such as the Encyclopaedia Britannica. From the use of *pozzolana* in Rome, it leaps to Smeaton and Aspdin. The history of concrete outlined by the British Science Museum on its website today follows the exact same narrative from 'ancient cements' to 'modern cements'. See: https://www.britannica.com/technology/cement-building-material and https://www.sciencemuseum.org.uk/objects-and-stories/everyday-wonders/building-modern-world-concrete-and-our-environment. This perspective also informs popular books on cement and concrete, such as Per Jahern and Tongbo Sui, *History of Concrete: A Very Old and Modern Material* (Singapore: World Scientific Publishing, 2017) and Robert Courland, *Concrete Planet: The Strange and Fascinating Story of the World's Most Common Man-Made Material* (New York: Prometheus, 2011).

The clues to begin pursuing an alternate history of cement, in fact, can be found in Carey's own remarks. After a detailed discussion on the technical dimensions of manufacturing, testing, and using Portland Cement, Carey concluded his lecture this:

> We are approaching an Artificial Stone Age…Your knowledge of fortification and military engineering will enable you to appreciate, and I trust, take advantage of [this material]…In the hasty defence of many a tight place a few bags of cement and a little wire netting would have been invaluable. The distinguished force to which, I trust, you are destined to add fresh lustre, is not only concerned with the defence of a world-wide Empire, but has to learn the art of devoting infinite pains to apparently trivial matters. It is in the nice adjustment of means to end that such trivialities may change the old order of things.[8]

Just as the use of cement and concrete "contributed to the application of the term "Eternal City", to Rome, he seemed to be assuring the Royal Engineers, Portland Cement would enable an 'eternal empire'.[9] What Carey's words and the context of their utterance reveal is that cement's history was not only shaped by manufacturers and engineers in Britain, but was also necessarily a military past that unfolded within the framework of the empire.

From the early decades of the nineteenth century to that of the twentieth, one of the most important networks which cement and concrete were part of was that of the military and scientific endeavors of the Corps of Royal Engineers and other colonial civil engineers. In fact, it is almost impossible to study the early history of cementitious materials in isolation from the activities of these engineers, for they played the most important role in embedding cements onto the emerging networks of circulation of knowledge and application in this period. The sites where these materials were assimilated into engineering practice, consequently, were spread around the globe, across colonies and the metropole.

These engineer officers occupied a unique position in the empire. They held wide ranging and varied military and civil appointments at home as well as the colonies at multiple levels- as the Corps, in civil and military stations, and as individuals. Especially as the Corps, they were regarded as 'scientific' men who enjoyed high status as professionals in society, and were well-positioned to be instrumental in building bodies of knowledge on building technology and new materials through experimentation.[10] They often took up the roles of many occupations - architect engineer, surveyor, building contractor, scientist, manufacturer, manager and educator -

[8] Carey, *op. cit.,* p. 20.
[9] *Minutes of Proceedings of the Institution of Civil Engineers*, ICE, Vol XVI (1856-57): p. 441.
[10] John Weiler, *Army Architects: The Royal Engineers and the Development of Building Technology in the Nineteenth Century* (University of York, 1987), pp. xv, xiii.

simultaneously. Precisely because of these multiple roles, they were involved in the development of building technologies in multiple capacities, in experimenting and testing, manufacture of materials, education and technical writing, design, management and supervision as well as the inspection of works.[11] Further, the continuous and growing interactions between engineers across the empire in this period of professionalization led to the constitution of a body of scientific literature on building technologies and materials.[12] Thus, the unique position endowed them by the empire opens a window for us to trace the accompanying movements of cement across the globe.

Borrowing insights from the social studies of science, this chapter attempts to look at science and technology *in action*, identifying locales where technical knowledge evolved through practice. For instance, Latour looks at two sites, laboratories and literature, focusing on the process of 'fact-making' which is far from straight-forward. He also looks at controversies, alignments and personalities and how they shape the literature that comes to constitute scientific knowledge.[13] Jahnavi Phalkey's recent work on atomic science in twentieth century India, along this line, attempts to look at science as practice, by tracing the activities of a cohort of scientists working within institutions, focusing on the negotiations between the political-administrative concerns and laboratory practice.[14]

The early history of cement and concrete also yields archives which principally highlight a particular group, the 'experts' or engineers, over others like construction workers and labourers. A question then emerges: how can we write a history of cement and concrete without it becoming a history of the engineers who worked with these materials? Further, how can one write a history which balances the human and the material, the socio-political and the technical? One way to do this, is to place at the centre of the analysis the *process* through which expertise comes to be constituted, rather than at the *application* of expert knowledge.

As Phalkey's writes,

> I do not centre my narrative on institutions and individuals but on their particle accelerator-building activities for nuclear physics research and education. If material culture is the physical world shaped by people and artefacts through intention and action, the particle accelerators…embody aspirations, positions, negotiations, and the efforts of patrons, mentors, builders, and users…The accelerators

[11] *Ibid.,* p. xvii.
[12] *Ibid.,* p. xviii.
[13] Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society* (Cambridge, MA: Harvard University Press, 2015).
[14] Jahnavi Phalkey, *Atomic State: Big Science in Twentieth-Century India* (Ranikhet: Permanent Black, 2013).

> provide a tangible anchor to trace links between scientists, technicians, the state, funding agencies, and industry, as well as local and international politics.[15]

With cement as a 'tangible anchor', this chapter delves into the science of these materials in action, and the links between the expert engineers and materials in the networks of an empire.[16]

However, as Kapil Raj reminds us, it is vital that while a metaphor of the network has an "ability to include human, material and semiotic elements and deal with them in a symmetrical manner", the linkages between them must not be seen as linear, blind to the physical distances between the actors or the hierarchies of power between them.[17] Further, "the effects of institutions, institutional and group allegiances, organic solidarities, education, and norms and canons of civility" within networks need to be as carefully examined as individual agencies.[18] Raj's proposition, then, is to employ the concept of 'spaces of circulation' which is more "sensitive to the asymmetries of power" that is involved in processes of knowledge formation. These spaces are "bounded and unevenly landscaped", and are both physical and social. They are physical, because they are circumscribed to specific places, regions or areas. They are social because specialist practitioners strive to keep forms of knowledge contained to specific social groups or institutions which share not only material elements like instruments or books, but also values, education, norms and other immaterial ties.[19]

The story of cement and engineers in the nineteenth century, is a story of how the knowledge of materials came to be embedded in one such space of circulation. The locales where cement and concrete 'came to be', and where scientific and technical narratives about them were constructed, firstly, involved the experimental endeavours of colonial engineers in sites ranging from Chatham to Calcutta. The second important element of this space was the scientific and technical literature published from and circulated in both regions by institutionalized bodies of engineers. These sites were far from discrete, and often, the divisions between the laboratory and the field, the experimenter and the writer, and the scientist and the chronicler were blurred.

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[15] *Ibid.,* p. 8.

[16] The frameworks of network theory, in recent years, has been used to re-examine science in the empire by questioning the monolithic concept of 'colonial science'. Most notably, Bennett and Hodge use the concept of networks to examine the evolution of forestry education and agricultural science, highlighting hybridities and the incorporation of local knowledges. Brett Bennett and Joseph Hodge, *Science and Empire: Knowledge and Networks of Science Across the British Empire, 1800-1970* (Hampshire: Palgrave Macmillan, 2011).

[17] Kapil Raj, "Networks of knowledge, or spaces of circulation? The birth of British cartography in colonial south Asia in the late eighteenth century", *Global Intellectual History* 27, no. 1 (2017): p. 51.

[18] *Ibid.,* pp.51-52.

[19] *Ibid.,* pp. 52-53.

In fact, the scientific and technical understanding of cement by engineers in this period is inalienable from their narrative knowing of these materials. As recent theorizations of science as narrative argue, practitioners or narrators include in their accounts, "contingent and tacit details to an extent that can seem to go beyond their immediate scientific purpose." [20] Their narratives not only endow a sense of coherence to seemingly disjunctive elements of their scientific or technological practice, but also allow the space for "twists, turns, and contingencies, paths not taken, opportunities forgone, even moments of regret".[21] What this reimagination of scientific and technical literature challenges, is the idea of objectivity so often attached to modern scientific practice. In other words, objectivity has not been the only source of credibility for the knowledges produced by practitioners of science and technology. "What counts as explanation, and understanding, within a science depends less on a universal ideal, than on what satisfies the scientific norms and values and shared knowledge set of a community." [22]

Building on these perspectives, this chapter begins by considering the various early experiments conducted by the Royal Engineers and other colonial engineers, before moving on to scrutinize the technical literature which constituted the corpus of knowledge on the materials for engineers across the globe. These interactions reveal markedly decentralized -yet intertwined- trajectories. Further, the circulated knowledges on these materials often surpassed the parameters of the 'technical' and involved processual accounts and narratives from construction sites which were as valuable to the larger body of knowledge as the metrics and results of experimentation on the ground. In seeking to write a history of cement and concrete, our investigations, thus, begins at the spaces where they *emerged* as material technologies in the nineteenth century.

[20] Mat Paskins and Mary Morgan, *An Anthology of Narrative Science* (London: Narrative Science: 2019), p 8.
[21] Mary Morgan and Norton Wise, "Narrative science and narrative knowing. Introduction to special issue on narrative science", *Studies in History and Philosophy of Science*, 62 (2017): pp. 3,4,5.
[22] *Ibid.,* pp. 10, 12.

Cements in the Metropole: Royal Engineers and Military Experiments

The early history of cement and concrete is by no means a linear progression from the use of limes and natural cementitious materials to the invention of modern artificial cement and a subsequent smooth replacement. Rather, since the 'discovery' of artificial cement in the early nineteenth century, the history of its use and spread was paralleled by many decades of small and large-scale experiments, failures and contingencies. This section will take a closer look at these through the experimental endeavours of Royal Engineers in nineteenth century Britain.

The early experimentation on hydraulic cements in Britain were centred around Chatham, under General Charles William Pasley, the Director of the Royal Military Establishment. Chatham lies on the east bank of the Medway, and is continuous with the ancient city of Rochester.[23] The town developed around a Royal Navy Dockyard which was established here as early as the sixteenth century, and later gave rise to multiple Army barracks and forts in the nineteenth century. A hundred years before the military experiments discussed in this section, voyager Monsieur Aubert de la Motraye wrote that

> Chatham is the ordinary and the safest Harbour of the Great British Fleet, the Houses for Sea-Officers, Directors, Inspectors, Workmen, are extraordinarily well built. A numerous variety of Stately Buildings environing spatious Tards cover'd or spread, for great part, with Cannons, Mortars, Bullets, Bombs; with Anchors, Iron unwrought and other Things that can resist to the injuries of the weather, of divers high and large Magazines stored with all that belong to the equipping and fitting out the greatest Fleet that ever any other power was able to keep…[24]

Clearly, Chatham had been a site of immense military significance long before the site had been chosen as the location for setting up the Royal Engineer's Establishment (School of Military Engineering after 1869) under General Charles William Pasley. In 1826 when the study of building was added to the course of training for British engineer officers for the first time, Pasley undertook certain experiments and published treatises on cementitious materials with the objective to create an artificial hydraulic cement, and to determine the feasibility of fusing this material as mortar. A closer look at these experiments can furnish important insights into the contingencies involved in experimenting with materials.

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[23] The Chatham district lies within the country of Kent, but, north of the large area occupied by estuary-waters of the Thames, is included also a small part of land in the county of Essex.

[24] William Brenchley-Rye, "Visits to Rochester and Chatham Made by Royal, Noble and Distinguished Personages, English and Foreign, from the Year 1300 to 1783," *Archaeologia Cantiana* 6 (1866): p. 78

The most striking aspect of Pasley's experiments is how much their failures or success depended on what he called ‘accidents’. At the earliest stages of his endeavour, in 1826, Pasley was faced with repeated failures for many months, until in 1828 when Major Reid, a friend of his, requested the former to demonstrate the method he had been using create an artificial cement. Pasley was reluctant, sure that such a demonstration would lead to certain failure. However, when Reid reiterated his strong wish to see the experiments, Pasley complied, and to their surprise, an artificial water cement was successfully formed this time. In tracing the roots of this discrepancy, Pasley discovered that upon being asked to mix two parts of pulverized chalk and one part of clay together without further specifications, the soldier he had employed to assist him had used the blue clay of Medway (which was available nearest to the spot), rather than the brown one used in previous experiments (which was brought two miles away from Darland). Fortunately for Pasley, the Medway clay was being used by the Corps to secure the powder-houses of experimental military mines when prepared for explosion, and was, by chance, readily available nearby. Thus, by “mere accident”, a series of failed experiments transformed into hundreds of successful ones, and culminated in the formularization of artificial cement. [25]

The fact that experimenting with cement was deeply contingent on factors beyond the control of the expert is also illustrated by the difficulties faced in attempting to replicate small-scale experiments on a greater scale. After having ‘accidentally’ discovered a good artificial water cement, Pasley’s process of testing evolved into the creation of experimental balls not more than 1 inch in diameter, consisting of various proportions of the ingredients each, and burning them in crucibles. Attempts were made to break these after one or two months, to determine their relative strengths and properties.[26] Based on this experiment, Pasley made definite conclusions about the best possible combinations of ingredients to produce good cement. However, when it came to replicating these small-scale tests on the ground on a greater scale, Pasley found himself facing difficulties from unexpected quarters.

Though technically he had arrived at ideal proportions, when it came to mixing the ingredients to create larger structures, Pasley faced repeated failures. The first time apparently the “workmen had not taken sufficient pains in making and mixing it, the cubes being coarse grained and porous”, as a result of which he “threw the whole of this mixture away” and adopted the process of washing to “remedy these imperfections”, which resulted in its failure. The second failure was

[25] Charles William Pasley, *Observations on Limes, Calcareous Cements, Mortars, Stuccos and Concrete, and on Puzzolanas, Natural and Artificial.* (London: J. Weale, 1838), p. 2.
[26] *Ibid.,* pp. 43-45.

attributed to the mixture having been spoiled by too long exposure to air, and Pasley concluded that the length of the period necessary for changing the mixture from good to bad depended upon the size of the lumps into which it is made.[27] The next time around, the failure was ascribed to the fact that the kiln he sent the mixture to had employed a new foreman who "obstinately persisted in applying the fewel to the raw cement cubes, in the same way that he had been accustomed to…in consequence of which all the artificial cement put into his hands was completely vitrified, so that we were obliged to throw it away."[28] In sum, Pasley now had to factor into his experiments many - mainly human- variables which were beyond his control, and which his expertise could not manipulate.

Finally, the first satisfactory experiments on a large scale were carried out in 1831 and 1832, after having "found it necessary to take the whole process into my own hands, by employing Private James Menzies…" to personally oversee the mixing, moulding and burning.[29] Yet once again, in the absence of this assistant, who had taken ill during the preparation of a batch in 1831, the product proved defective. Pasley notes how this "circumstance was very discouraging to me, as success seemed to depend upon one individual; for the men who made it, declared that they had followed the same proportions and mode of proceeding, that he had done, in every respect."[30] Pasley himself was acutely aware of how contingent his scientific experiments were on 'extra-scientific' elements. He therefore resorted to "interrogating them more strictly", only to find out that the man "who had served out the pulverized chalk had compressed it…as closely as he could, so that he forced a much greater quantity into the same space than had ever been used before."[31] Pasley's experiments therefore also involved, in some measure, investigative endeavours into the human errors which one might do well to call contingencies rather than 'accidents'.

As Merton and Barber have argued, understanding the role of 'accidents' complicates the typical understanding of science as an entirely 'rational' enterprise based solely on arguments and observations, and forces us to take into account other factors such as general and broad research planning, the degree of autonomy of the individual scientists within an organization, their ability to shift their attention to strategic, unexpected phenomena, and the institutional conditions for creative research and research evaluation at the individual and organizational levels.[32] Beyond

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[27] *Ibid.,* pp. 64- 66.
[28] *Ibid*.
[29] *Ibid.,* p. 67.
[30] *Ibid.,* p. 69.
[31] *Ibid.,* p. 70.
[32] Robert K. Merton and Elinor Barber, *Travels and Adventures of Serendipity* (Princeton: Princeton University Press, 2011).

‘accidents’, Pasley’s experiments involved certain other extra-scientific elements, such as public confidence. For instance, he was keen on having credible witnesses to the tests he conducted on the strength of cement. In 1837, in what Weiler calls “the Victorian tradition of materials-testing publicity stunts” where seeing amounted to believing, Pasley tore apart two stones which had been joined with his artificial cement in the presence of several officers of the Royal Engineers, the chairman the Chairman of the East India Company, the naval superintendent of Chatham dockyard, as well as others including tradesmen and mechanics. [33] Thus, Pasley’s experiments with cement reveal much about the very nature of scientific enterprise.

After many years of experimentation, Pasley finally published his results as a treatise in 1838. The very context of the publication of this work is illuminative of the nature of research on cement in this early phase. Between the first sheets were sent to the press and the final publication of the treatise, almost two years had passed, “owing to new questions concerning the properties of cements continually suggesting themselves…besides which time was repeatedly lost by unforeseen failures in our apparatus.” Pasley writes:

> during this period also, as our views became more enlarged, the common modes of experimenting on the comparative strength of cements and mortars, which we had at first adopted, appeared to be unsatisfactory, so that in addition to these, we had recourse to a new method for ascertaining their comparative adhesiveness to bricks and stones, which is in fact their most important property, but to which little or no attention had been paid by former writers. This also was of course a cause of delay.[34]

Indeed, Pasley’s work was published at a time when cement and concrete were under constant and novel forms of re-examinations, for this was a period when these materials were receiving unprecedented attention as a construction material.

In this context, Weiler traces the interlinked transformations in military technology and defence policy in the nineteenth century. After the Napoleonic Wars the prevailing attitude in Britain was one of invulnerability, especially when it came to naval power, and by the late eighteenth century, drastic cuts in military expenditure had begun. However, “changes in the technology of warships and artillery, along with the course of events in European international relations, were to effect a transformation in the government's attitude towards land defences and consequently to the construction of fortifications.” [35] In the mid-nineteenth century, the challenge that Britain faced

[33] Weiler, “Army Architects”, *op. cit.,* p. 50.
[34] Pasley, *op. cit.,* p. 1.
[35] Weiler, *op. cit.,* p. 179.

in the context of a rapid arms race, came in the form of ironclad warships with more accurate and powerful guns which not only threatened naval supremacy, but also made it vulnerable to invasion, and inadequate coastal fortification emerged as the weak link in Britain's defence. [36] Both Pasley's experiments and other military projects using cement and concrete were thus made possible by the climate of support and incentive for experiment and innovation.

The first mention of the use of concrete in British military construction can be traced back to 1826, the same year when Pasley started his research on hydraulic cements. In the 1830s, when British military construction primarily involved brick or stone masonry, there were few instances of the use of hydraulic cements in a military capacity.[37] Pasley had been experimenting since the 1820s, but it was the increased government spending on fort construction from the 1860s that allowed the Corps to experiment with the material on a larger scale. Further, though his research had led to valuable results, Pasley himself believed that concrete was not a reliable material for military construction.[38] This opinion was maintained by the Corps into the 1830s and 1840s. However, In the 1850s, Capt. H.Y.B. Scott created a natural hydraulic cement both stronger and less expensive than the material which was being used for government construction at the time, Blue Lias.[39] Scott's Cement was further only half as expensive as Portland Cement, and was recommended for use as mortar, render and in marine works. Scott also promoted its use as a component of concrete.[40]

In the 1840s and 1850s, the use of concrete remained marginal and restricted to applications such as water-proofing brick casemate arches, damp-proofing floors for magazines, foundations and other such minor structural uses. Though the use of concrete in military projects remained relatively rare in the 1860s, it was in this period that widespread research and interest in the material took root. [41] By the early years of the decade, Capt. Scott and Capt. Frances Fowke had started suggesting the use of concrete in fortification. They argued that masonry was expensive, slow, and required highly skilled labour. In order to reduce costs, the tendency was to build escarps as low as possible, and to reduce casemates and bombproofs to the minimum, and to

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[36] *Ibid.,* p. 181.
[37] Andrew Powter, "History, Deterioration, and Repair of Cement and Concrete in Nineteenth Century Fortifications Constructed by the Royal Engineers," *Bulletin of the Association for Preservation Technology* 10, no. 3 (1978). The first was the rendering of a casemate vault at Chatham in 1830 to prevent rainwater from destroying the mortar, and the second, an experimental casemate at Woolwich in 1835.
[38] *Ibid.,* 62.
[39] Blue Lias is a geologic formation in southern, eastern and western England and parts of South Wales, part of the Lias Group. It consists of a sequence of limestone and shale layers, laid down in latest Triassic and early Jurassic times, between 195 and 200 million years ago.
[40] *Ibid.,* p. 63. He continued publishing his results in the following years, in 1857, 1861 and 1862.
[41] *Ibid.,* p. 65.

substitute masonry with earthwork whenever possible- all of which compromised on defensive capability. By substituting concrete for brick and stone, they argued, the construction of magazines, casemates and ditch revetments could allow for the mechanizing of a larger portion of the construction process. Pasley's influential position within the Corps meant that this idea was resisted. Finally, in 1862, after further research, Scott refuted Pasley's conclusions point by point, and in 1865, the first British fortress which used concrete extensively was built in Newhaven Sussex.[42] Constructed with Ranger's patent concrete, the latter was an experimental project to see whether concrete and artificial stone could be used for fortification where stone or brick clay were unavailable.[43] The material was left to harden for two months, and then then bombarded with 13 in. mortar and 25 lb. cannon fire. Though the construction withstood the bombardment, the fact that the concrete was slow to set was pointed out as a disadvantage for large projects. This was one of the earliest of the artillery trials, which would become regular in the later decades.[44]

Many early military experiments with concrete, unlike Pasley's scaled-down balls, thus involved the bombardment of structures to determine the strength of the material. In 1866, a 68 pounder was fired at the Newhaven fort, a test which it successfully passed. The cracks which appeared on the structure was carefully measured, and it was concluded that they were a result of seasonal temperature variations. It was then recommended that in the future, concrete revetments ought to have dry-brick joints periodically, in order to allow movement.[45] In the latter half of the nineteenth century, as the sizes of the guns got bigger and the weight of the projectiles increased, newer tests and experiments were conducted for the effect of projectiles on building materials. The earliest British reference to such a trial by projectile was held in 1877 at Shoeburyness.[46] Between 1880 and 1884, similar experiments were carried out at Dungeness and Lydd as well, the details of which were published in 1884 by Lieutenant Colonel F. G. Bailey for all Royal Engineers to peruse.[47] By 1885, the general opinion on the basis of such tests was that concrete was to be preferred over hard masonry. Though projectiles could penetrate concrete twice as far as it could into granite, the ultimate damage was confined to the immediate surroundings of the path of the projectile. Granite, on the other hand, splintered dangerously, and several courses of

[42] *Ibid.,* 65.
[43] 1 Dorking lime:3 sand:5 gravel and 1 1/2 parts boiling water
[44] *Ibid.,* 63.
[45] *Ibid.,* 65.
[46] *Professional Papers of the Corps of Royal Engineers,* REI, Vol I (1877): p. 9.
[47] *Professional Papers of the Corps of Royal Engineers*, REI, Vol 10 (1884): p. 17.

masonry would be dislodged.[48] Destructibility, thus, was as important a metric of experimentation with materials to determine their relative strengths.

Concrete was, by now, being actively promoted for the construction of ditch revetments, floors, covers for bomb- proof chambers or even buildings for habitation.[49] One can observe that many of these uses were employed in the Chatham ring of land forts "if not with enthusiasm and vision, at least with some confidence and awareness of the potential of the material."[50] The early Chatham forts (1875-1885) were built mainly in concrete, brick now reduced to a smaller extent. Further, both the plastic and monolithic character of concrete were made full use of in the construction of various elements such as casemates, ditch revetments, tunnels, water tanks and magazines as well as details like splayed rifle loops, gun ports, and decorative moulding which were cast in-situ. In more complex features like caponiers, counterscarp galleries, and the fort entrances, "this material really began to come into its own."[51]

Restoration architect Andrew Powter asks, "Why was concrete used for revetments only and not for other structures in the fort? Why was it used only in a protected location unlikely to be exposed to enemy fire? Why was concrete suddenly acceptable to the British military?" These are fascinating questions, and Powter speculates one of the reasons to be that "in the face of parliamentary cuts in the construction programme, the military could no longer afford to neglect an economical material and decided to give it a try, at a site less likely to have to undergo heavy bombardment than the main harbours."[52]

The history of experimentation by Royal Engineers in Britain taken up in this section reveal, firstly, that science of cement and concrete was not merely a matter of discovering a formula of ideal proportions in a controlled setting, but rather an enterprise which occurred in multiple locales- be it the laboratory, kilns, fortifications or walls, always subject to natural or human contingencies. This science also depended on the larger context of a climate of support for continued experimentation and application. In writing a history of cement, however, these engagements cannot be considered in isolation. They were part of a larger matrix of experimentation carried out by engineers across the globe.

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[48] *Professional Papers of the Corps of Royal Engineers*, REI, Vol 3 (1879): p. 298.
[49] Powter, *op. cit.,* p. 67.
[50] *Ibid.*
[51] *Ibid.*
[52] *Ibid.,* pp. 59, 66.

Cements in the Colony: from 'Native' Mortars to New Materials

The engineer officers of the East India Company were amalgamated with the Royal Engineers in 1862 and had been educated at the Royal Engineer Establishment since 1817. [53] The testing and application of new materials formed the most important aspect of the engineer's role in the colonies, and this included experimentations with limes and cements.[54]

The engineer in India, irrespective of origins and assignment, had to be an 'all-rounder' who could convert his knowledge and skills to multiple civil and military engineering projects, often on short notice, and still be able to complete the project on time and to specification. Further, he was also entrusted with bureaucratic responsibilities, and had to be flexible with local conditions and customs, for instance with respect to the hiring and firing of local labour and dealing with Indian subcontractors.[55] In other words, the engineer's identity often transcended that of the 'scientific soldier' or a technical expert.

Accordingly, the training needed to create such men of multifaceted responsibilities had to consist not merely of theories and 'technical facts' or principles of civil engineering, but also information on 'how to be' on the ground. For instance, *The Roorkee Treatise on Civil Engineering in India*, originally put together by Royal Engineer Lieutenant Col. J. G Medley in 1866, dealt with subjects which required special treatment to suit the climate and methods used in India.[56] Though this text also considered 'universally applicable' principles of irrigation engineering, the method of their instruction were often framed by thorough local knowledge, the

[53] After the amalgamation, in 1870-71, the Royal Engineer establishment had 817 members of which 395 were stationed in India, 237 of which were in the Public Works Department. In comparison, between 1809 and 1861, a total of 500 engineer officers were posted in India. See Weiler, *op. cit.,* p. 3.
[54] John Weiler, "Colonial Connections: Royal Engineers and Building Technology Transfer in the Nineteenth Century." *Construction History* 12, 1996, p.4.
[55] *Ibid*., p. 231. This is corroborated by Ramnath' study where he points to the multiplicity of the engineer's duties. For instance, Assistant Engineers often had to negotiate contracts, establish rates, assess finished work, and draw up bills, and a Superintending Engineer was often an administrator who had to supervise budgets and account issues. See: Aparajith Ramnath, *The Birth of an Indian Profession: Engineers, Industry, and the State, 1900-47* (New Delhi, India: Oxford University Press, 2017): pp.118-119.
[56] *The Roorkee Treatise on Civil Engineering in India* was published from the Thomason College of Civil Engineering at Roorkee, which was established in 1847 to meet the increasing demand for skilled overseers and technical men in the Ganges Canal project. As John Black argues, no comparable text was available in Britain, and the very existence of the treatise reveals that the Thomason College was teaching the theory and practice of engineering technology rather than merely extending the practical man ethos supported by practical engineering instruction, as was the case in Britain. See: John Black, "The Military Influence on Engineering Education in Britain and India, 1848–1906," *The Indian Economic & Social History Review* 46, no. 2 (2009): p. 229.

importance of adapting to local circumstances, elements such as the physical particularities of the locations and the need for local informants.[57]

The course that Medley traced for an engineer's career reflects the special requirements demanded of an engineer in India: he had to have practical knowledge and the ability to operate on the ground without much supervision, on quick notice, in an efficient manner, and often in the absence of supporting infrastructure.[58] With such work, Medley warned,

> he will find great interest and no small anxiety; he will have to look after or do nearly everything himself, without the aid of clever contractors, skilled clerks of the works, and intelligent foremen; he will probably have to train his own subordinates, to work with very inefficient plant, and to trust to his own resources every day, and under circumstances calculated to try his mother-wit, his common sense, and clear-headedness, above all, his patience and temper, in a way he never calculated on.[59]

The financial and budgetary duties of the engineers were also detailed by Medley; the engineers must, as he put it, "cut their coat according to their cloth." [60] Once this is done, he needs to get the work executed by contract, as is possible in larger presidency towns, or rely on contracts for earthworks and materials, and employ paid labourers for the rest himself. It might also fall on him to "import labourers from other districts, to organize them into gangs, provide them with tools and arrange for their food, water, and temporary shelter."[61]

The training given to engineers, thus, constantly attempted to balance theory and practice. This 'practice', however, was not merely a straightforward application of theory, but rather entailed

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[57] Michael Lewis, "The Personal Equation: Political Economy and Social Technology on India's Canals, 1850–1930," *Modern Asian Studies* 41, no. 05 (2007): p. 973.

[58] Julius George Medley, *The Roorkee Treatise on Civil Engineering in India (Vol II), 3rd Edition*. (Roorkee: Thomason College Press, 1878): p. 41. Tracing the career of a young engineer in India, Medley says that upon landing in Bombay and reporting to the military authorities, he would be redirected to Roorkee where a year's duty with the Sappers and Miners is expected of him, during which time he is also expected to obtain some knowledge of local languages and customs. However, often, before the year is completed, "the young officer will read in the Gazette of India one fine morning that his services have been placed at the disposal of the P.W. Dept,; and in the next Gazette that he is posted to such or such a province; then a week later, in the local Gazette of that province, he will be posted to a particular circle, and the superintending engineer of that circle will desire him to report himself to some particular executive engineer. The day after his arrival he will find himself employed according to the nature of the work, either surveying and levelling, or drawing plans and making calculations, or in a tent in the middle of the jungles superintending the building of a bridge, with not a soul that can speak a word of English within 30 miles of him. For the next four or five years he will probably be changed about a good deal from one work to another; and if he has proved himself efficient, will then find himself an executive engineer of the fourth grade, and in charge of a division; while, after running through the four executive grades, another ten years or so may carry him on to the higher grade of a superintending engineer." *Ibid.,* p. 43.

[59] *Ibid.,* 46.

[60] *Ibid.,* 48.

[61] *Ibid.*

many dimensions of existing on the field as an engineer. For instance, in discussing building materials, Medley points to not just strength and durability, but also "facility of working" as the three most important principles to choose the best material. In fact, the latter is the inverse of the former qualities, in that it points to the degree to which a material is 'workable'-which needs to take into account the availability of labour, proximity of the material, cost, climate etc. The puzzle, as the author states, "is in striking a medium between these conflicting qualities."[62] Each material, their distribution and availability across the geographical plane of India and their relative costs in different regions were recorded to equip the engineer to strike such a medium. In case the engineer had to source his own material, as was often the case in India, detailed notes on quarrying and on how to raise and deliver the stone in the least expensive manner were taught.[63] Additionally, specifications on building in rainy weather, damp conditions, dry climates, and under specific local customs such as the east-west orientation of the building were highlighted.[64]

The nature of experimentation with cement and concrete in South Asia was shaped by these particular characteristics and demands of the engineering occupation. In the section on 'Limes, Cements, Mortars, Concrete and Plasters', Medley proclaimed

> thorough analysis of limestone is an operation which few Engineers know enough of chemistry to perform for themselves; nor have they often either the apparatus or time required to enter on it.[65]

Occasionally, this early pedagogic framework also assumed a *tabula rasa.* Though various kinds of limes and mortars had always been in use in South Asia, the engineer was asked to resort to his five senses to identify the material, rather than rely on local knowledges:

> The stone ought to be bluish gray, brown, or of some darkish color, as white indicates pure limestone or gypsum. On being touched by the tongue, the presence of clay ought to be quite perceptible to the taste. It should also be detected by its smell after wetting.[66]

From the earliest construction projects of the colonial engineers, the struggle to procure construction materials was rampant. As early as the construction of Fort William in the late seventeenth century, local lime was used along with bricks. Royal Engineer Sandes wrote later

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[62] *Ibid.,* pp. 2-3.
[63] *Ibid.,* p. 20.
[64] *Ibid.,* pp. 3, 15, 31, 32.
[65] *Ibid.,* p. 113.
[66] *Ibid.*

that the engineers at the time had to resort to manufacturing the lime themselves rather than relying on sellers.[67] This struggle continued into the nineteenth century. For instance, during the construction of the Sirhind Canal from 1874 in Punjab, the engineers "had to dig and burn their own lime [and] made their own kilns and bricks"[68]

Limestone and limes created by burning them, were not singular materials either. The diverse geological landscape of India yielded a variety of limestones used for building purposes, including calcareous *tufa*, limestone boulders, and *kunkur*.[69] *Tufa,* a material formed when limestone is dissolved in carbonated water creating a deposit at the surface, was found primarily in the hilly districts. It was used profusely in those districts in the Gangetic plains which bordered the hills. Limestone boulders were found in the Sivalik region and the outer Himalayan ranges, and were favoured because they did not require quarrying. Yet, engineers expressed hesitation to adopt these materials. "Tufa being essentially a local deposit," advised Medley, "its extent must be carefully estimated before much reliance can be placed on it. This stone [however] is admirably adapted for native use…".[70] Similarly, limestone boulders did not bend to the norms of engineers. As Medley wrote, "the chief objection to lime from such a source, is its uncertain quality if nicety be required."[71] Royal Engineer Captain E. Fraser had, apparently, attempted to make lime out of these stones at Roorkee only to find a surprisingly high amount of 'inconsistency' in composition:

> In a small basketful of the pebbles, one may find a dozen different varieties of stone from as many different beds of the anciently denuded rocks of the Himalayas [72]

Compared to these limestones, *kunkur* found a more prominent place in the works of the engineers in India. Colonel P. T Cautley, who engineered the Ganges canal project, engaged with this material on various occasions. Mostly found in the plains, this material was procured from the vicinities of *jheels* or wetland areas.[73] Particularly relevant was the fact that they made excellent water-cements, suitable for use in hydraulic engineering works.[74] It also required little

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[67] E. W. C Sandes, *The Military Engineer in India, I,* 1933, p. 124.
[68] E. W. C Sandes, *The Military Engineer in India, II,* 1935, p. 13. See Radhika Singha, "The Short Career of the Indian Labour Corps in France, 1917–1919," *International Labour and Working-Class History* 87 (2015): pp. 27-62, for a description of how Royal Engineers might have acquired expertise on the burning of limes from lime burners by tradition in the Indian Labour Corps.
[69] Medley, *op. cit.,* p. 107
[70] *Ibid.*
[71] *Ibid.*
[72] *Ibid.*
[73] *Ibid.*
[74] *Ibid.,* p. 148.

to no added *surkhi* (powdered burnt brick) for its strength, as it already contained a high concentration of clay.[75] Engineers, therefore, were invested in prospecting and 'finding' new varieties of *kunkur.* For instance, "a remarkably fine kind of kunkur lime" was found at Behmurri in Gorakhpur, which later won first prize at the North Western Provinces Exhibition in 1867. This 'Behmurri lime' reportedly had higher adhesive properties than the ordinary *kunkur* in use, and this made it well suited to a wide array of uses including plastering floors and reinforcing walls.[76]

Apart from limestones, there were other unique forms of cement used in different parts of the subcontinent. Sandes, for instance, refers to a kind of lime plaster which was used in Madras called *channam* (*or chunam*), which was made from the shells of a very large species of oyster. These shells, "when burnt, pounded and mixed with water, form the strongest cement imaginable", he quotes. If used as plaster, this was mixed with egg-whites or milk. This material was purportedly as "as beautiful as marble."[77] Pasley himself, while claiming that the "natives of India have had no knowledge of water cements, similar to those of England", attributes sections of his treatise to "the superior Mortars or Stuccos made in India,"[78] referring to *chunam*. The extent of the use of *chunam* in India, however, was limited by its particular material constitution. When the same shells were brought to Calcutta from the Coromandel coast and mixed in the same manner and with the same materials, they could not achieve the similar marble-like sheen because the water in Bengal had too much saltpeter in it.[79]

The method of making artificial water cement, closest to what we may call 'modern' cement, was introduced in Calcutta as early as 1831 by Lieutenant W.W. Saunders of the Madras Engineers, who conveyed to the Asiatic Society the method that Pasley had formulated. Saunders had previously been under Pasley's command at Chatham and had witnessed the latter's many experiments. His own experiments proved that in the terrain of Calcutta, some *kunkurs* or limestones required less clay than common lime to make a water cement, in contrast to England.

Based on Pasley's early pamphlets on cement, a communication was sent to the Court of Directors of the East India Company in 1837, recommending that the carbonate of magnesia - which was abundant in parts of the Madras Presidency- be used as a water cement in public works. Pasley was "gratified by the reflection that an experiment of mine, from which I never

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[75] *Ibid.,* p. 146. *Surkhi* is brick pulverized. It is then mixed with lime to form a mortar
[76] *Ibid.,* p. 147.
[77] Sandes, *op. cit., The Military Engineer in India, I*, p. 82.
[78] Pasley, *op. cit.,* 112.
[79] Sandes, *op. cit., The Military Engineer in India, I*, p. 132.

anticipated any practical result, owing to the great expense of magnesia in this country [Britain], should have proved useful in that distant part of the globe."[80]

In truth, the properties of the carbonates of magnesia had been identified a few years prior by Mr. J Macleod, a surgeon in the Company's service, and had already been put to application in Madras to discover a hydraulic cement to be used as a substitute for English water cement in India. Macleod had conducted his experiments on the walls of Fort St. George and reported his results as early as 1827 to the Military Board as well as to a Royal Engineer named Sir. Frederick Adam. Subsequently, a committee of engineers was formed to experiment with magnesian cement from Salem. Thomas Munro himself perused its final report and expressed "a confident hope of their ultimate success."[81]

There were numerous officers experimenting with cements on an individual capacity distinct from the experimental routes taken at Chatham. One such engineer was Captain John Thomas Smith of the Madras Engineers.[82] In 1837, he translated French engineer Louis J. Vicat's work on artificial limes and other cementitious materials (published 1828) under the title: *A Practical and Scientific Treatise on Calcareous Mortars and Cements, Artificial and Natural*. At the time, this was the second ever book on mortar and cements to be published in English. The work contained additions based on his own experiments, and "proved to be especially influential with engineer officers in India and rivalled Pasley's work…"[83]

Through his interest in Vicat, Smith developed a preference for hydraulic limes in the French tradition, over natural cements or artificial cements advocated by Pasley.[84] This preference was also owing to the fact that unlike in England where the builder's dependence on the manufacturer was not significant, in India, despite their slower setting, hydraulic limes had the advantage of easy production, in that they simply had to be burnt. No special skills or machinery were required.[85] Smith also experimented with the new material, called 'magnesia cement', which was

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[80] *Ibid.,* 114.
[81] *Ibid.*
[82] After 1856, he became consulting engineer to the Madras Irrigation Company and a director of the Madras Railway Company and later its chairman. In 1845 Smith founded the *Professional Papers of the Madras Engineers* and edited its first three volumes.
[83] Weiler, *op. cit., Army Architects,* p. 368.
[84] Hydraulic lime is a general term for varieties of lime which set by means of hydration. These differ from varieties of air limes, which set through carbonation. Nnatural cement is obtained by burning and then grinding up stones which contain clay, carbonates of lime, and carbonates of magnesia. Artificial cements, on the other hand, are made by burning together, a mixture of calcareous and argillaceous materials at extremely high temperatures. The main difference between them lies in the process of manufacture.
[85] *Ibid.,* 369.

a natural hydraulic cement made from magnesian limestone.[86] Tests were undertaken by Madras engineers by comparing a mixture of sand and magnesia cement with a mixture of lime, iron stone and common *chunam* plaster, and it was found that after a heavy monsoon, the former proved stronger.[87] In the 1830s, new deposits of magnesia were found in Salem and Trichinopoly which made the material more accessible and therefore economic in use.[88]

Magnesia cement was used by many engineers for constructing irrigation works, most notably by Arthur Cotton of the Madras Engineers. Cotton was gazetted to the Madras Engineers at the young age of sixteen in 1819, and in the four decades of his career in the region (he returned to England in 1861), had established himself as one of the most distinguished irrigation engineers and a great authority and referee on matters of dam-building. In 1834, he conducted multiple experiments using magnesian limestone from different quarries by tweaking the proportion of sand in the mixture, as well as by making small cubes of brickwork to test adhesion. He then daringly employed this material in an important irrigation project in 1847-52, a dam across Godavari at Dowalishwaram present day in Andhra Pradesh. Like Pasley, Cotton's experiments were also highly contingent on various elements beyond his control. For instance, when a particular batch of his magnesia cement would not set, he could find no other explanation except for the nature of that particular batch of stones he had used.[89]

Thus, in the early decades of the century, compared to Pasley's experiments at the central establishment at Chatham, the experiments in the colony were often conducted at the sites of construction where the individual engineer happened to be located.

Soon, in comparison to the earlier modes of decentralized and localized encounters and experiments and in the presence of an institutional and infrastructural framework with its own conventions and rules of experimentation, cements began to be embedded in a system of formalized knowledge. As both the profession of engineering and its channels of communication became increasingly formalized, a Cement Experiments Division was set up in Calcutta. In the 1870s. The Executive Engineer of this Division, P. Dejoux, carried out extensive experiments on the strength of Indian cements and circulated his findings in tabular form for all engineers working in India.[90] Dejoux's experiments are interesting also for the ways in which the relationship between cement and other materials involved in its constitution, was schematized.

[86] Magnesian Limestone is a suite of carbonate rocks in north-east England dating from the Permian period.
[87] Weiler, *op. cit.,* "Colonial Connections.", p. 4.
[88] Weiler, *op. cit., Army Architects*, p. 370.
[89] *Ibid.,* 371.
[90] *Professional Papers on Indian Engineering,* Thomason Roorkee Press (1876): p. 21.

In testing for the quality of Portland Cement manufactured in Calcutta, for instance, Dejoux's variables included not only the proportions of cement, but also the various 'qualities' of water used to mix the batches.[91] His tests also made him hostile towards limestone and *surkhi*, which he considered corruptive, an attitude some others came to imbibe.

The urge to prospect, discover, and put to use newer kinds of cements remained alive in these new institutional contexts. Dejoux himself was interested in the possibilities of extracting stronger, cheaper and easily available new materials. "I think", he wrote:

> … a patient and deliberate exploration of the range of hills from Margohi to Rohtas, will lead to the discovery of several varieties of useful stones. I intend to carry out a careful research personally…[92]

Subsequently he experimented with what he called 'Margohi' cement, made from materials obtained from the Margohi quarries located near Dehri in Bihar.[93] After tweaking samples made from gray limestone, yellow clay and 'ghooting stones' (nodular limestone), Dejoux finally concluded that good cement could be made out of these 'ghooting stones' from Margohi.[94] As always, there remained 'unexplored' landscapes and 'new cements to be 'discovered'.

The experiments and encounters described in this section were channels through which cement was brought into formalized engineering knowledge in the nineteenth century. They not only reveal the contingent nature of engineering practice, but the ways in which it worked to render cementitious materials knowable, and more precisely, useable. As we will see, this accumulated body of technical knowledge, circulated through professional journals, was also a space where cement 'came into being'.

[91] P. Dejoux, "Experiments on strength of Indian cements," *Professional Papers on Indian Engineering* (1876) pp. 229-237.
[92] Medley, *op. cit.,* p. xix.
[93]*Ibid.* To conduct his experiments, he hired one of Messrs' Burn and Company's s*urkhi* mills at Bow Bazaar in Calcutta at Rs. 18 per day.
[94] Medley, *op. cit.,* p. ix-xxxiii.

Writing Cement: Technical Knowledge as Narrative

The process of bringing cement into the professional and technical literature of military and civil engineers was not automatic. In the initial years of the publication of the new version of the *Professional Papers of the Corps of Royal Engineers,* papers on construction and civil engineering works, and consequently building materials, were virtually absent. In 1878, thus, secretary of the Royal Engineers Institute Robert Vetch, Major, R.E, wrote,

> while the present volume contains a great deal of interesting matter connected with the primary duties of the Corps,- its military duties, there is an absence of information on points of construction and civil engineering, which, considering the very large number of officers employed in India on the public works, and the importance of the works executed, not only in India and the Colonies, but also at home by Engineer Officers, is much to be regretted.[95]

He then reiterated his statement from a previous volume, urging "his brother officers" to write about their experiences working on particular projects so that "a rich store of experience would be accumulated in our publications for the assistance and guidance of the Corps."[96] However the dearth of papers on construction and civil engineering ceased to be a problem only by the 1890s, when the publication came to contain "papers on most of the branches of the Corps duty, as well as on essentially military subjects."[97]

It was one thing to survey, experiment, and build with cement on the ground; it was another one altogether, to *write* about these activities. Engineers therefore often resorted to *narrating* their experiences of building and experimenting in a subjective, intersectional and chronological manner, to present information in a coherent format. These accounts, therefore, are marked by the individual presence of the engineer. Often times, the question of choice of material, technology and design were not presented in such technical or scientific terms in these narratives, but instead the entire construction process was described meticulously. Descriptions of the difficulties faced during construction, problems of labour, positive and negative outcomes of various material and design choices were all included.

Another reason why engineers perhaps employed narrative telling of their experiences rather than abstracted information, could be the fact that their motives were primarily to facilitate the

[95] *Professional Papers of the Corps of Royal Engineers*, REI, Vol II (1878): p. 1.
[96] *Ibid.*
[97] *Professional Papers of the Corps of Royal Engineers*, REI, Vol XVI (1890): p. 1.

work of other engineers. For instance, Captain G.K Scott- Moncrieff's prefaced his account on *The Frontier Railways in India* in 1885 by stating that the

> details I am about to describe are those that were new to me personally, and to almost every officer in our Corps…I shall…be glad if by relating our experience I can give some of my hearers an idea of how to set about their work, if they should have similar work to do. I shall try to point out the practical lessons which I, in common with others, learned on this great work.[98]

In narrating the account of the construction of the Sind Peshin State Railway, Moncrieff also highlighted how the specific preferences of the Engineer-in-Chief guided construction, rather than any standards or specifications:

> Engineer-in-Chief liked always to inspect the site before the concrete was put in, so that he might satisfy himself as to the thorough soundness of the rock-bed on which the pier was to be built… [I]n mixing the concrete the Engineer-in- Chief directed that the sand and cement should first be measured and mixed dry, and then mixed with the measured shingle, also dry. During this second mixing water was sprinkled in very moderate quantity.[99]

In recounting such instances as embedded in a narrative, Moncrieff seems to be proposing to his audience of engineers across the globe a model of mixing cement without necessarily taking accountability for it.

Narrativizing the use of cement was also a way in which it came to be separated from what was being constituted as 'nature' by modern scientific enterprise. The virtues of cement, for engineers, were defined by its resistance to natural elements: water, fire, heat and even frost.[100] An unexpected natural element that engineers, particularly in India, had to come to terms with, was vermin. In their choice of materials, they consistently had to account for imperviousness to vermin, a contingency which shaped their decisions over the thickness of structures, as for instance at the Soonkesala canal in Madras..[101] Here, cement came to the rescue. As an engineer wrote in 1871,

> In India…vermin were a source of great annoyance and danger…They forced their way through the loose stones…but in order to prevent the heat of the sun and vermin [the engineer] covered it with a pitching in Portland Cement, through which vermin could not penetrate.[102]

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[98] *Professional Papers of the Corps of Royal Engineers*, Vol XI (1885): p. 249.
[99] *Ibid.,* p. 243.
[100] For discussions on fireproof and frost- proof cements as well was the impact of 'natural' elements on cement, see: *Minutes of the Proceedings of the Institution of Civil Engineers* volumes from1897, 1890 and 1888.
[101] "The Soonkesala Canal", *Minutes of Proceedings of the Institution of Civil Engineers,* ICE (1871): pp. 72, 82,83.
[102] *Ibid.,* 102.

However, not all engineers appreciated the increasing predominance of cement and concrete, and internal tensions remained. In 1885, Captain G. S Clarke, R.E called cement concrete the "bane of the Engineer." He wrote,

> A wall built of the stone of the country soon loses its visibility, weathering down to a mellow hue, and, where it is not expensively pointed at intervals, clothing itself with a rich garment of lichen. Hard rendered surfaces of cement concrete weather little, look like nothing in nature... Even at Malta, an island of white stone, concrete powerfully asserts itself, and insists on being seen… This is as it should be, in the case, say, of a monument; but does not fulfill all the requirements of a magazine of explosives turned towards, and within 2,000 yards of an enemy's possible position. Devil's Gap Battery, Gibraltar, again, is a white concrete wart on the grey-green western slopes of the Rock. [103]

Whether Clarke's concern has to do primarily with the problem of too much visibility-and hence vulnerability with respect to military strategy- with the aesthetics of materials remains ambiguous.[104] As Forty points out, the view that concrete was somehow different from other materials was prevalent in this period, and considerable amount of effort had been put into 'naturalizing' it. The fact that concrete does not 'age' like stone or other 'natural' materials and that it does not 'go to ruin' added to this apprehension.[105] It is this concern which perhaps manifests in Clarke's comments as well.

The language of engineers also betrays their sense of anxiety over the fact that cement often tended to not bend absolutely to their wills. Thus, the "behaviour" of cement could involve "tricks", making it a material "we need to humour" in order to elicit the outcome one wanted. Cement was also capable of "bleeding" and "escaping".[106] Cement could also be "prejudicial" to the materials engineers added to it, such as sand or brick power, and thus had to be carefully handled.[107]

Two general characteristics of these engineering narratives ought to be mentioned here. First is the way cement assumed shifting identities. The tension between the quality and cost of cement constantly figured in these accounts, as engineers switched between viewing it as a material and a commodity depending on the nature of their narrative. Second, it is the narrative nature of engineering knowledge that also brought into it, discussions of labour. Needless to say, technical journals became, to an extent, the platform where engineers expressed their irritations over what

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[103] *Professional Papers of the Corps of Royal Engineers*, REI, Vol XI (1885): p. 200.
[104] Adrian Forty, *Concrete and Culture: A Material History* (London: Reaktion Books, 2016), p. 44.
[105] *Ibid.,* p. 52.
[106] *Professional Papers of the Corps of Royal Engineers*, REI, Vol XV (1889): p. 50.
[107] *Professional Papers on Indian Engineering* (1872): p. 604.

they perceived to be unskilled or idle labour. While this is not surprising, it reveals how the hierarchies that began emerging between materials reinforced the hierarchies of labour that emerged with the consolidation of engineering expertise.

In sum, while the material contingencies of cement on the ground shaped engineering practice, the narrative elements inherent to the circulating bodies of knowledge in turn mediated the identities of cement as a material.

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This chapter brought into focus an important and relatively overlooked history of cement in the nineteenth century: the experimentations and narrativizations of this material by military and civil engineers in the nineteenth century. Cement in various forms not only existed, but also 'came into being' both materially and conceptually in localized sites spread across the globe. What we have discovered in this chapter, thus, is that industrially produced cement had a sundry past in nineteenth century.

One of the reasons why this history of engineering connected to cement has often been overshadowed, is because the material has largely found place in the scholarship on architectural design, or industrial histories. Yet, it is to a history of manufacture that this thesis must now turn, not only with the aim to record the emergence and growth of cement industries, but to examine how one kind of cement- Portland Cement- came to replace the myriad of cements discussed in this chapter.

Chapter Two

Making 'Grey Gold': Portland Cement in India c. 1900-1945

For centuries, engineers and scientific experts had experimented with cementitious materials to arrive at that perfect mixture of cement which was not only materially sound, but also economic. This had resulted, as we saw in the previous chapter, in a prolonged and history of trials, accidents, failures, exchanges and debates across the globe. Yet, it was not a chemist or an engineer, but rather a bricklayer who had arrived at the process of manufacturing a cement that would, over the course of the subsequent centuries, come to dominate the global built environment.[1] Around the same time as Pasley's experiments, a mason in Leeds called Joseph Aspdin mixed and burned clay and chalk together to create what has been called a 'proto' Portland Cement.[2] In the 1840s and 1850s, Aspdin and his son William went into the business of selling this Portland Cement.[3] Since its very conception, Portland Cement was thus an industrial material.

This chapter attempts to trace the evolution of this new material, often referred to today by the epithet 'grey gold', through a history of its industrial and technical development in the early twentieth century India. Beginning with an account of its early uses, this discussion moves on to chart the dynamics of the Portland Cement industry in this region, and how the material became inextricably entangled with the labels of modernity and progress. An underlying

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[1] "Joseph Aspdin," *Science Progress in the Twentieth Century (1919-1933)* 19, no. 75 (1925): p. 494.

[2] See previous chapter for details regarding Pasley's experiments.

[3] Though he called it 'Portland Cement' in his 1824 patent, Aspdin's cement was slightly different from what Portland Cement actually came to be a few decades later. In his patent, Aspdin described his method of making the cement as follows: "I take a specific quantity of limestone, such as that generally used for making or repairing of roads, and I take it from the roads after it has been reduced to a puddle or a powder; but if I cannot procure a sufficient quantity of the above from the roads I obtain the limestone itself, and cause it to be calcined. I then take a specific quantity of argillaceous earth or clay and mix them with water to a state approaching impalpability. After this I put the mixture in a slip pan for evaporation until the water is entirely evaporated. Then I break the mixture into suitable lumps and calcine them in a furnace similar to a lime kiln until the carbonic acid is entirely expelled. The mixture so calcined is ground, beat, or rolled to a fine powder and is then in a fit state for making cement or artificial stone." See Richard W. Steiger, "The History of Concrete," *The Aberdeen Group* (1995): p.1. In the mid-1840s, another manufacturer Isaac Johnson increased the temperature at which this cement was processed, which resulted in a better end product. Richard Meade, a century later, described Portland Cement in a vastly different and formulized way, as "the product obtained by finely pulverizing clinker [he stony residue from burnt coal or from a furnace] produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum." See Richard Meade, *Portland Cement: Its Composition, Raw Materials, Manufacture, Testing and Analysis* (Easton: The Chemical Publishing Company, 1926): p. 16.

argument of this chapter is that the existence and popularity of Portland Cement had as much to do with the rhetoric of the engineers and manufacturers as its inherent material qualities like strength and durability. In taking this position, this chapter suggests that the adoption of new materials and technologies is not a self-evident matter of course which happens once a new invention or discovery is made, but rather a deeply social process dependent on numerous material and human forces in interaction with each other.

A New Material: the Early Days of Portland Cement

Portland Cement first came to the attention of British civil engineers in the 1850s. When John Grant, Assistant-Engineer to the Metropolitan Board of Works, specified Portland Cement for the construction of the main drainage works of London, the material found a major place in the civil constructions in England.[4] British engineers and industrialists had always worked closely together in experimenting with and popularising the use of Portland Cement throughout the latter half of the nineteenth century. This is evident, for instance, in the consistent presence of G. F White, of Messrs. White & Co., at the meetings of the Institution of Civil Engineers. Messrs. White and Co., was a pioneering cement manufacturer who had borrowed Aspdin's method in 1845 and set up one of the largest Portland Cement plants on the river Thames, at a time when natural cements such as Parker's 'Roman Cement' were more in demand.[5]

Years before Grant had chosen Portland Cement for the London drainage project, White had declared to the members of the Institution his reservations with Pasley's artificial cement, and described the greater cohesive strength, in his opinion, of "the stronger but more costly material known as Portland Cement."[6] However, as a manufacturer, White's praise for Portland Cement was bound to attract little faith, and he was always aware of this. At a meeting of the Institution in 1852, he responded to predicted criticism by questioning the "invidious" doubts of a German

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[4] *Minutes of Proceedings of the Institution of Civil Engineers*, Institution of Civil Engineers, Vol. XXV (1865-66): p. 66. Also see: "John Grant", *Grace's Guide to British Industrial History, h*ttps://www.gracesguide.co.uk/John_Grant

[5] Dylan Moore, "John Bazley White & Brothers," *Cement Kilns,* May 31, 2011; and "John Bazley-White and Brothers," *Grace's Guide to British Industrial History,* https://www.gracesguide.co.uk/John_Bazley-White_and_Brothers.

[6] *Minutes of Proceedings of the Institution of Civil Engineers*, ICE, Vol XI (1851-52): pp. 507, 508. Interestingly, Pasley argued a few years later that he himself had originally suggested the production of an artificial cement, of his own formula, to Messrs. White who at first continued to prefer natural cements, but had later plagiarized his method and by "sinking the term artificial, had disguised the cement made from these materials, under the name of Portland cement…" See *Minutes* Vol. XVI (1856-57): p. 443.

engineer "whether the experiments made by Messrs. White on Roman and Portland Cements, accurately exhibited the relative merits of the two materials…[as] being manufacturers of Portland Cement only, it was natural for them to depreciate the other."[7] White was quick to deflect any possible doubt about his experiments by playing into national sentiments and turning it into a question of 'English' manufacturers being disparaged by the French and the Germans.[8] In 1871, expressing his obligation to John Grant, who by this time had become an authority in Portland Cement, White also acknowledged that as an industrialist, he needed an engineer to legitimize his findings:

> He might say that in his own works there were recorded thousands of experiments for years past on the strength of cement; but he could well understand that no trials made by a manufacturer on his own material could have for the members of the Institution the same value as those conducted by an independent engineer.[9]

The increasing use and popularity of Portland Cement in nineteenth century Britain, therefore, was a result of a long friendship between engineers and manufacturers. By the early 1880s, however, some engineers had become critical of British manufacturers' excessive focus on certain experiments with the sole aim of cheapening production costs, rather than increasing quality. Henry Reid, for instance, urged Messrs. White to "direct their attention to a more reliable measure of quantities and a better admixture", rather than on the utilisation of waste heat.[10]

The high cost of manufacture remained a major concern for manufacturers until the development of the continuous process rotary-kiln in the mid-1880s which helped reduce fuel intake by a huge margin.[11] Towards the end of the century, many new companies employing up-to-date technical processes began emerging in competition with each other. Finally, in an attempt to reduce internal competition and imports, the Associated Portland Cement Manufacturers Ltd. (later called the Blue Circle) was formed in 1900 through a merger of 24 companies. When this failed to prevent the shutting down of many plants, in 1911, 33 companies merged to form the British Portland Cement Manufacturers Ltd, controlling, by this

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[7] *Minutes of Proceedings of the Institution of Civil Engineers*, ICE, Vol XI (1851-52): p. 509.
[8] *Ibid*.
[9] *Minutes of Proceedings of the Institution of Civil Engineers*, ICE, Vol. XXXII (1870-71): p. 316.
[10] *Minutes of Proceedings of the Institution of Civil Engineers*, ICE, Vol. LXII (1880): pp. 191, 192.
[11] This cylindrical furnace would rotate with the material being stirred inside as hot gases were passed through the kiln. This technology also allowed for the simultaneous mixing and calcination as opposed to grinding after heating. See Bertram Blount, *Cement* (London: Longmans, Green and Co, 1920). Also see: "Portland Cement Manufacture," *Times of India*, 23 December 1910.

time, 80% of the total British production.[12] Throughout this period of industrial expansion, British manufacturers had been exporting cement not only to European countries like France and Germany, but across the world to locations even as remote as the Ushruffee Islands in the Red Sea.[13]

The use of Portland Cement in South Asia can be traced to the 1860s, when it was employed on a large scale for the construction of the Kurrachee Harbour in the form of concrete blocks to construct the breakwater.[14] It was also used on smaller scales, for instance, at the Nagpur waterworks in the 1870s as protective coverings for pipes.[15] It was employed for similar coating purposes at the Rajkot Waterworks in Bombay as well, in the early 1890s.[16] Unsurprisingly, the early uses for Portland Cement were mostly in structures which came into contact with water, for its hydraulic and quick-setting properties made it more water-resistant than other cements. However, in the absence of local production, high costs primarily owing to freight charges continued to hinder more widespread use. British Civil Engineer Bindon Blood Stoney expressed the issue of costs concisely in 1874 during a discussion on the construction of the Kurrachee Harbour,

> The present price of the best Portland Cement in London was from 45*s*. To 55*s*. per ton, free on board. The cost of the casks to export it to India was 20*s*. each; the freight was 40*s*.; making collectively 5*l*. 10*s*.,to which was to be added the cost of primage, landing and storing, making in all 5*l*. 15*s*. [17]

There were attempts to manufacture Portland Cement locally, as evidenced by the existence of the Indian Portland Cement Company in Calcutta in the early 1880s, which had supplied the necessary cement for the reconstruction of the Bhimtal Dam in Kumaon.[18] However, this venture presumably did not last long, for less than a decade later, in 1895, the walls of the Kidderpur Docks in Calcutta were built with clay and brickwork because "there was no other material other than broken bricks obtainable in Calcutta suitable for making concrete...Suitable

[12] A. J Francis, *The Cement Industry, 1796-1914: A History* (Newton Abbot: David and Charles, 1978).
[13] *Minutes of Proceedings of the Institution of Civil Engineers*, ICE, Vol. XXIII (1863-64).
[14] *Minutes of Proceedings of the Institution of Civil Engineers*, ICE, Vol. XXXVII, Part I (1873-74) and Vol. XLIII, Part III (1875-76).
[15] *Minutes of Proceedings of the Institution of Civil Engineers*, ICE, Vol. XXXIX, Part I (1874-75).
[16] *Minutes of Proceedings of the Institution of Civil Engineers*, ICE, Vol. CXIX (1895).
[17] *Minutes of Proceedings of the Institution of Civil Engineers*, ICE, Vol. XXXVII Part I (1873-74): p. 376.
[18] *Minutes of Proceedings of the Institution of Civil Engineers,* ICE, Vol. LXXV (1884): p. 206. See George Watt, *A Dictionary of the Economic Products of India* (Cambridge: Cambridge University Press, 2014) for information on the Portland Cement Company in Calcutta.

concrete could only have been made with cement, which would have to be imported…[and] would have cost about Rs. 55 per 100 cubic feet while brickwork in ghooting lime cost Rs.30."[19]

Towards the end of the nineteenth century, a new technology of construction started gaining prominence: reinforced concrete.[20] As some in the industry eloquently put it, "cement is to concrete as flour is to cake"; and the basic ingredient of reinforced concrete, apart from steel, was Portland Cement.[21] In South Asia, reinforced concrete had begun replacing timber, steel and masonry, especially in the construction of bridges, by the early 1900s. Owing to the low cost of labour in India, structures which would have been built in steel had they been located in Europe, were constructed in concrete here.[22] The earliest reinforced concrete bridges in the subcontinent date back to 1901, when two small bridges were designed by Major E.R. B Stokes-Roberts, R.E, each spanning 9.15 m. A mere decade later, in 1911, the largest reinforced concrete bridge in India at the time- Afzal Ganj Bridge- was built in Hyderabad, with four arches spanning 54 m each.[23]

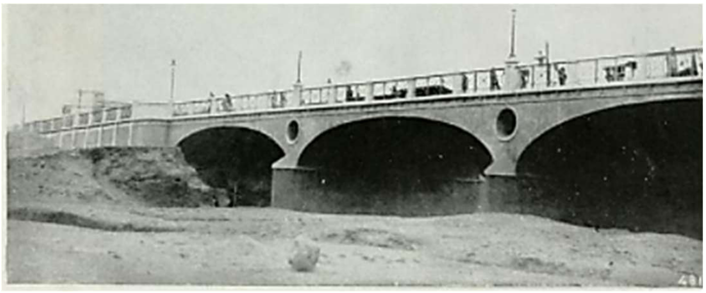

Figure 1: The Afzal Ganj Bridge, Hyderabad. *Concrete and Constructional Engineering,* Vol 7, No. 4, 1913, p. 145

[19] *Minutes of Proceedings of the Institution of Civil Engineers,* ICE, Vol. XCCI (1895): p. 139.
[20] Concrete has a relatively low tensile strength and ductility, which leads to cracks under pressure. In Reinforced Concrete Construction (RCC), this is prevented by internal reinforcement of materials with high tensile strength and ductility, such as steel or iron. French engineers and architects are typically considered the pioneers of reinforced concrete (especially Monier, Cottancin and Hennebique). According to architectural historian Adrian Forty, the French made some "far reaching claims for the French proprietorship of reinforced concrete…[portraying it] as 'the radiation of French thought and creativity across the world'". Interestingly, they ignored the contributions of German engineers who had first developed the mathematical methods for the structural analysis of reinforced concrete, churning out manuals and magazines in the 1880s, whereas the French pioneers had mostly relied on trial-and-error methods. Forty also points to the reluctance of Americans to lay claim to Reinforced Concrete in the early twentieth century owing to "misgivings as to whether it could truly be considered an 'industrial' material". It required craft labour for the construction of formwork, which did not correspond to the American industrial principle of mass production. See Adrian Forty, *Concrete and Culture: A Material History* (London: Reaktion Books, 2016), pp. 104-108. See: Charles Marsh, *Reinforced Concrete* (New York: D. Van Nostrand Company, 1904) for the descriptions of this construction method as it was practiced in this period.
[21] *Modern Marvels: Concrete,* by Mark Mohr, Geographic History, The History Channel, 2000.
[22] Stuart Tappin, "The Early Use of Reinforced Concrete in India," *Construction History* 18 (2002): p. 86. Another consequence of cheap labour was that mechanized mixers were rarely used and concrete was mixed on the ground and carried to the site in small loads by workers, resulting in quality issues in the structures. See p. 84.
[23] *Ibid.,* pp. 85-86.

Modernizing princely states like Travancore, with well-established PWD departments, adopted reinforced concrete early on.[24] According to the Travancore Administration Report of 1927, "all the most important buildings and bridges were constructed of reinforced concrete, a method of building which has been carried on during the past 27 years by the Public Works Department with great success and efficacy."[25] However, it was in urban areas like Bombay with a growing population and a higher demand for larger structures, that the technology became most prevalent.[26]

This mounting popularity of reinforced concrete construction was reflected in and propelled by the immense optimism of its advocates at the time. As early as 1910, *Concrete and Constructional Engineering* reported that "reinforced concrete structures are seen in many sections of Bombay and are likely to be the base of all new structures such as tenements, warehouses, etc.…Reinforced concrete is *the* building material."[27] Similarly, writing about the use of concrete in cotton mills in 1918, Harold Holt stated that

> … when the wooden-post structures of Spain and Italy and the bamboo and mud factories of India have been swept away, as they are bound to be, there is nothing left for it in such countries but reinforced concrete, again and all the time.[28]

By the early twentieth century, in sum, the demand for Portland Cement in India had risen to unprecedented levels due to the rising number of public works and the popularity of reinforced concrete. The extent to which Portland Cement was required "for Public Works and construction work generally in India is shown by the imports which, for the three years prior to the War, 1912-14, averaged about 3,000,000 cwts per annum."[29] Of this, 84% came from the United Kingdom, and the rest from Germany, Belguim, Italy, Austria and Hong Kong.[30] At this

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[24] Sadasyatilaka T. K. Velu Pillai, *The Travancore State Manual*, Trivandrum: The Government of Travancore, 1940, pp. 156, 163.
[25] *Travancore Administration* Report, Trivandrum: Superintendent Government Press, 1928, p. 124.
[26] Tappin, *op. cit.* By the late 1920s many indigenous architectural and engineering practices had come into existence which specialized in reinforced concrete construction. The *chawls* for mill workers in Bombay was built in 1922, and official buildings such as the Revenue Offices in Karachi was completed in 1921. Various housing and office buildings were also built in Bombay at this time, such as the four-storey students hostel built in 1907 for the Victoria Jubilee Technical Institute, or the Bombay House in the early 1920s, which was the headquarters of the Tata group of companies. The famous 'Cement House' opposite Churchgate station in Bombay, which was the office of the Associated Cement Companies, was constructed in the late 1930s. See pp. 80-83. Also see: "Bombay Industries No. 16: Reinforced Concrete Construction: A History to Date," *Times of India,* 5 August 1926.
[27] *Concrete and Constructional Engineering*, Volume 4, No. 1 (1909): p 9. [Emphasis original]
[28] *Concrete and Constructional Engineering*, Vol 13, No 6 (1918): p. 841.
[29] Henry Musgrave, *Report on Portland Cement of Indian Manufacture*, Indian Munitions Board, Government of India, 1919, p.1. [1 cwts = 112 pounds].
[30] *Ibid.*

time, the demand in India was so high that agents in London were buying German cement for re-export to India under the brand name "Gladiator."[31] Between 1900 and 1913 the total import of cement had increased from 43,000 tons to 1,80.000 tons.[32] However, with the commencement of the war, internal demand for reconstruction had grown in Europe and issues of freight became prevalent, restricting import to a great extent.[33] Therefore, as Indian capital moved into arenas hitherto underdeveloped by foreign capital- such as sugar, jute, paper, iron and steel etc- in the early twentieth century, it was almost inevitable that Portland Cement would be one such industry.

Portland Cement and Inter-war Industrialization

Although a cement company was started in 1904 in Madras by South India Industrials Limited using shells as its basic raw material, it became defunct after the First World War, mainly due to low demand in the region. When Portland Cement industries started cropping up in the second decade of the twentieth century, they were therefore scattered closer to the centre of concentrated capital as well as urban construction. All three of the first Portland Cement companies in India developed geographically around Bombay and functioned under managing houses based in the city.[34]

The first of these, the Indian Cement Company managed by Tata, set up a factory in Porbandar, Gujarat in 1914. They marketed their brand as 'Ganapati Best Portland Cement'.[35] In 1915, the Katni Cement Company Ltd. started operating from the Central Provinces under the management of C. MacDonald and Company, with the brand name 'Castle'.[36] The plans for this factory had been put in place as early as 1906 when a syndicate of businessmen found, upon prospecting, large deposits of clay and limestone in this region.[37] The third of the

[31] Tappin, *op. cit.,* p. 82.
[32] Indian Tariff Board, *Report Regarding the Grant of Protection to the Cement Industry*, Calcutta: Government of India, 1925, p. 7.
[33] "Indian Cement Factories: Impending Developments," *Times of India,* 9 March 1920.
[34] Amiya Kumar Bagchi, *Private Investment in India, 1900-1939* (Cambridge: Cambridge University Press, 2008), p. 353.
[35] Tappin, *op. cit.,* p. 82.
[36] This brand, along with the Jubbalpore 'Lotus' brand, was later used in the construction of Lutyens's Delhi. "Indian Portland Cements, their use at New Delhi", *Times of India,* 25 April 1924.
[37] "Indian Cement: A Visit to Katni," *Times of India,* 30 July 1915.

pioneering companies, Bundi Portland Cement Company Ltd., was located in Rajputana, and was managed by Killick, Nixon and Co.[38]

From early on, these three companies entered into an agreement with the Indian Munitions Board to sell cement to the Government. However, this arrangement would soon prove taxing to the manufacturers. In 1919, the managing houses of the three companies complained to the Board that though earlier they were allowed to sell a quarter of their monthly output to the public, currently the entire output of their factories were being requisitioned for military and government purposes under the agreement, and that there was "little prospect of any substantial proportion being released for sale to the public."[39] This, they believed, would lead to "the loss of markets which we have cultivated and which are learning to use and appreciate indigenous cement". Arguing that Indian public consumers had to rely on Japanese and other imported cements at exorbitant prices, and which are not being requisitioned by the government in a similar manner, they pointed to the discrepancy between the declared average values and the actual *bazar* rates of imported cements.[40] Given the rising costs of labour and coal (which was crucial to the burning process), and the difficulties in procuring machine replacements, they requested that any renewal of the agreement would fix higher prices.[41]

The government, however, was not fully amenable to these suggestions. They countered that owing to the high cost of sea freights, the cost of the imported article was bound to be higher than indigenous cement, and that local supplies were in any case insufficient to meet the needs of the region.[42] The Board then proposed certain steps which they hoped would "prove sufficient to afford the local industry a just measure of protection."[43] Stating that "it is desirous of extending to the public when possible, whatever advantage Government sources for itself", the Board informed the companies of its decision "to take over control of the distribution of the

[38] Bagchi, *op. cit.,* p. 353. and "Bombay Industries No. 5: Cement Manufacture: Indian Equals Best Imported," *Times of India,* 20 May 1926.
[39] "Demi-official letter from the Hon'ble member to Sir Thomas Birkett Messers. Killick Nixon and Co. Bombay regarding certain matters relating to Indian Cement Companies," Commerce and Industry, Branch: Industry, Progs. Nos. 1, 1918, National Archives of India, New Delhi, p. 4.
[40] *Ibid.,* p. 5. While the declared average value per ton of imported cement were Rs 99 in Bombay and 98.23 in Calcutta (including duties), the actual *bazar* rates were Rs. 250 for English cement, Rs. 200 for Japanese cement.
[41] *Ibid.,* p. 7. They proposed four alternatives to the government: ½ of the monthly output of respective works to be reserved for government at a price of Rs. 45 (excluding bags), balance left to companies to dispose as they desire; Or, ¾ of monthly output to be reserved for government at Rs. 52.8 (e.b), balance left to companies to dispose as they please; Or, the whole of the monthly works to be reserved for the government (for bonafide military works at Rs. 50 (e.b) and for government works at Rs. 62.8); Or, the whole output to be reserved for the government at Rs. 57.8 (e.b).
[42] *Ibid,* p. 10.
[43] *Ibid.,* p. 11.

whole of the outturn of your three companies…" at a rate of Rs. 55 per ton (excluding bags).[44] Any excess was to be made available to the public by the government as it saw fit, at the same rate.[45] To add insult to injury, the board then concluded its counter-offer with thinly-veiled reproval:

> It must be clearly understood that cement up to British Standard specification only is required. If inferior supplies be offered, Government reserves to itself the right to reduce the price to be paid for such cement, according to its measure of inferiority.[46]

The companies were, to say the least, surprised by these insinuations. They responded "with all due deference", that imported cements be subjected to the same rigorous censorship by Priority Committee and the Board as indigenous cements. This would, they suggested, lead to the finding that the "the demand for urgent works would not be much if any in excess of the local supply [and] That Government expenditure on works not of immediate moment would be reduced."[47] After questioning the efficiency of the Board in this manner, they agreed to the "dictum" in respect of price, but strongly protested the release of cement to the public at the same price. They took the Board's comments regarding this matter as an implication that the companies were attempting to "profiteer" at the expense of the public. This, they argued, could not be the case, as "our prices have always been much below the market price for imported cement, [and] no such charge can be laid to our door."[48] Additionally, arguing that the government took neither responsibility nor liability for providing the companies with sufficient coal as to produce the necessary quality of cement, they concluded that their "customers are thankful to get a first class Cement…Government intervention in respect of the prices at which we sell such quantities as may not be required for urgent Government Works in uncalled for."[49]

When Sir Thomas Birkett of Messrs. Killick Nixon and Co., attempted to obtain a fair deal in this exchange by approaching Sir George S. Barnes, a member of the Governor-General's Council in India, the latter replied rather curtly:

> I think that if you wish to appeal to the Government of India against the orders of the Munitions Board, you should do so officially. The Munitions Board is not responsible to me but to the Commander-in-Chief. I have, however, read your letter to the Munitions Board, and the impression

[44] *Ibid.*
[45] *Ibid.,* p. 11, 12.
[46] *Ibid.*
[47] *Ibid.,* p. 15.
[48] *Ibid.,* p. 15, 16.
[49] *Ibid.,* p. 17, 18.

> left on my mind is that the cement companies have not only been treated with consideration, but with liberality.[50]

This early exchange between the industrialists and the government foreshadowed the long history of control that cement manufacture would be under in the subsequent decades.

In 1919, a report written by Mr. Henry A. F Musgrave - Superintendent of Local Manufactures and Government Test House, Alipore, Calcutta - for the Indian Munitions Board concluded that these three early factories were “all modern concerns located at convenient sites, dealing with entirely suitable raw materials equipped with up-to-date machinery, efficiently staffed and under Expert European management; factories which compare favorably with those of well-known manufacturers at home.” He expressed his hope that the publication of his report would “serve to remove any prejudice against these brands of Indian cement which may remain in the public mind and lead to an expansion of the industry.”[51]

By 1924, six new companies had emerged, the total capacity of the factories nearing 6,00,000 tons per annum, with a total invested capital of 4.5 crores.[52] The total production of cement in India rose to 5,57,953 tons by 1928, in comparison to the meagre 945 tons in 1914.[53] By 1929, the ten existing companies together produced almost 90% of the total consumption in India in that year.[54] Such rapid development, with private investors investing independent from one another, ultimately led to excess capacity by the early 1920s.[55] In 1924, while the total demand in India was just short of 3,90,000 tons, the capacity of cement factories totaled 5,50,000 and was only expected to grow higher.[56]

In the same year, all of the existing companies applied for tariff protection.[57] Though the Indian Tariff Board recommended some protection (far less than what was proposed), the Government

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[50] *Ibid.,* p. 21.
[51] Musgrave, *op. cit.,* p.18.
[52] This was distributed among the following nine companies: The Central Provinces Portland Cement Co., Ltd. (111 lakh), The Dwarka Cement Co., Ltd (79 lakh), The Jubbalpore Portland Cement Co., Ltd. (54 lakh), The Katni Cement and Industrial Co., Ltd. (45 lakh), The Bundi Portland Cement Co., Ltd. (43 lakh), The Gwalior Cement Co., Ltd. (40 lakh), The Indian Cement Co., Ltd. (21 lakh), The Shahabad Cement Co., Ltd (12 lakh) andThe Punjab Portland Cement Co., Ltd. (52 lakh). *Times of India,* 09 May 1924.
[53] Alan Moncrieff, *Handbook and Directory Of The Concrete Industry In India* (Bombay: Concrete Association of India, 1929), p. 2.
[54] *Ibid.* Also see Tappin, *op. cit.,* p 82.
[55] Bagchi, *op. cit.,* p.355.
[56] *Ibid.* Also see Indian Tariff Board, *Protection to Cement Industry: Evidence Volume*, Calcutta: Government of India, 1924.
[57] Whereas the existing duty was Rs. 9 per ton, or 15 % on a tariff valuation of Rs. 60 a ton, the Indian companies asked for a duty of Rs. 25 a ton. They argued that since the principal market for cement in India were the ports, mainly Calcutta and Bombay, along with Madras, Rangoon and Karachi, and since up-country markets were more

considered internal rather than external competition as the prime issue of the industry, and did not grant protection.[58] Though the falling prices and technological changes led to the growing consumption of cement in this period, internal competition and excess capacity signalled trouble for the industry. The price of cement had fallen from over Rs. 70 in 1922, to Rs. 25 per ton (in some instances) by early 1925.[59] As prices continued to decline, companies began going into liquidation, and as a result, a series of 'quasi-monopolistic' institutions were set up by the industrialists to regulate the prices and promote the use of cement. The Indian Cement Manufacturers Association was set up in 1926 and the Concrete Association of India in 1930, under the efforts of industrialist F. E Dinshaw.[60] The Cement Marketing Company of India Limited was also set up in 1930.[61] The Cement Marketing Company soon came to control the sales of all companies and succeeded in stabilizing the price to an extent. It provided assistance to each factory, and spent a tremendous amount of its resources on promoting the use of Portland Cement as a material rather than the use of individual brands.[62]

Apart from the problems of unplanned development, the industry also faced prejudices against the indigenous product. A decade after Musgrave's optimistic report on Portland Cement of Indian manufacture, The Concrete Association of India, in 1929, had to admonish those who "are still inclined to believe that any material manufactured in India cannot be as good as the old imported article...and therefore steadfastly endeavour to obtain the imported article refusing to realise that the home product will give them better satisfaction at a lower cost."[63] They also argued that "Modern Portland Cement is a sensitive material and undoubtedly gives its best results when used in a climate and temperature similar to that in which it was manufactured", pleading that "if for no other reason then, for this alone Indian cement is obviously the best for use in India."[64]

Reservations regarding the quality of Indian Portland Cement were not completely unwarranted. At the Annual General Meeting of the Institution of Engineers in India in 1939, a

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or less dominated by Indian industries already, this tariff would allow the Indian cement industry to control all of the Indian market. *Ibid.,* p. ii.

[58] Indian Tariff Board, *Report Regarding the Grant of Protection*, *op. cit.* Also see "Bombay Industries No. 5", *op. cit.* The board also considered the high freight and transport costs of cement as a 'natural protection' enjoyed by the industry, just as the Munitions Board did a decade before.

[59] Bagchi, *op. cit.,* p. 356.

[60] RR Hattiangadi, "The development of the Cement Industry in India", *Times of India,* 29 June 1957.

[61] Bagchi, *op. cit.,* p. 357.

[62] *Ibid.*

[63] Moncrieff, *op. cit.,* "Preface".

[64] *Ibid.*

resolution was passed to look into the claim that "adulterated cements by mixing inferior brands or stone dust, … old stock affected by moisture, …[and] reground stuff of caked cement are being sold by cement stockists in India."[65] Many engineers argued that the main reason for such adulteration was the fact that the control of the sale of cement was completely in the hands of the Cement Marketing Co., with a very small margin of profit left to distributing agents.[66] They wondered, suggestively, why neither the company nor the Bombay City police were looking into the matter.[67]

Charges of adulteration continued to plague the industry well into the 1940s, leading the chairman of the ACC in 1946 to pre-emptively defend the company during a speech in the presence of Governor Hugh Dow:

> …without much in the way of assistance from the Government, we have been able to meet very largely the heavy demands made upon us for a product so essential to the prosecution of the war. What I would specially like to emphasis in this connection is that there has never been anything like a Black market in our cement, and we have supplied our products to Government and the public at a price which has actually given us a small margin of profit than realized by us in a normal year before the war.[68]

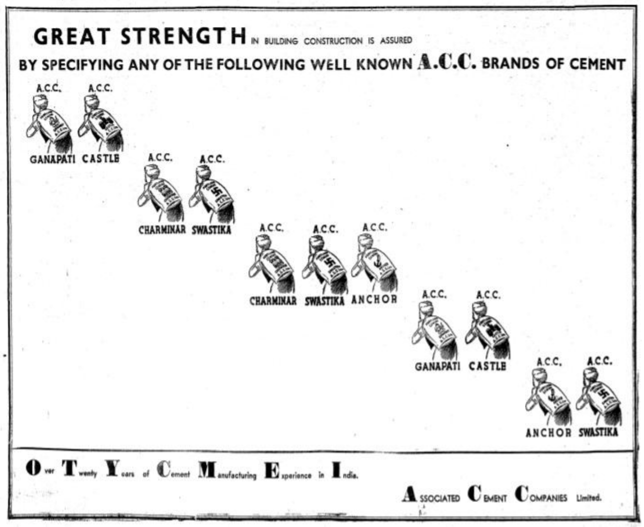

Figure 2: 'Great Strength': Advertisement for the Associated Cement Companies, Times of India, 6 Feb 1938: p. 8

[65] "Minutes of the adjourned Nineteenth Annual General Meeting", *The Journal of the Institution of Engineers (India),* Vo. XIX, No. 1 (September 1939): p. 19.
[66] "Activities of Local Centres", *The Journal of the Institution of Engineers (India),* Vol. XX (1941): p. 284.
[67] *Ibid.,* p.285.
[68] "Chaibasa Cement Works", *Indian Concrete Journal,* Supplement (December 1946): p. 5

However, as Kamnath argues, the fact that the state had been one of the biggest consumers of cement had allowed companies to profiteer through underground black markets in post-Independence India, at the cost of other consumers.[69] There is enough circumstantial evidence to assume that this was the case during the previous decades as well.

In 1936, ten of the twelve existing factories came together in a merger to form the Associated Cement Companies Limited (ACC) under the leadership of Dinshaw.[70] Many of the important business groups in Western India found representation in the board of directors of the newly constituted company. These included Sir Purushothamdas Thakurdas, J.R.D Tata, Sir Chunilal Mehta, Ambalal Sarabhai, Walchand Hirachand, Nowroji Saklatwala and many other prominent businessmen. However, the formation of the ACC did not eliminate the problem of internal competition entirely, for in 1938, a major competitor to the monopoly of ACC emerged in the East as the Dalmia-Jain group of companies set up their production.[71] This was the state of affairs in the Indian cement industry until the commencement of the Second World War.

Standardizing Cement: Codes, Pedagogy and New Hierarchies

As indicated at the onset, 'cement' had historically been used to describe different kinds of binding agents until the word came to popularly denote Portland Cement. The processes of delineating a distinct identity for Portland Cement were inextricably tied to concerns about the reliability, purity and quality of the material, as reflected in the impulse to celebrate it as the most superior form of cement. Outlining the difference between "genuine" Portland Cement and "Natural" cements, an industrial publication in 1913 emphasized how the former was distinct:

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[69] Shyam J. Kamath, *The Political Economy of Suppressed Markets: Controls, Rent Seeking and Interest Group Behaviour in the Indian Sugar and Cement Industries* (Delhi: Oxford University Press, 1992): pp.155-156.
[70] Hattiangadi, *op. cit.*
[71] Bagchi, *op. cit.,* p. 357. In 1938, the price of cement in Calcutta fell from Rs. 43 to Rs. 30 per ton, which was reflected in the profits of ACC which more than halved in a single year. This was ultimately solved when an agreement was reached between ACC and Dalmia to set up a joint selling organization with fixed prices and divvied up sales. See p. 358.

> Only by the use of *separate* raw materials, and by controlling their proportions from day to day, and even from hour to hour, and intimately mixing them prior to calcination…Cement produced in this manner is alone entitled to be considered genuine.[72]

This process is what made Portland Cement 'artificial', and it was this artificiality that made it 'genuine'.

Concrete and Constructional Engineering, published in London by Concrete Publications Ltd. since 1906, considered the chronicling of Portland Cement's increasing popularity its primary goal.[73] This 'chronicling' was an active process of singularizing cement which involved actively disparaging other 'cements' by assaulting their 'character', and not without practical effect. As the abovementioned editorial note concluded: "…the information concerning the true character of Belgian 'natural' cements which has from time to time appeared in these pages has undoubtedly done a good deal to discourage the use of a material of so uncertain and unreliable as a character."[74] Resistance to the proclaimed virtues of Portland Cement frustrated the proponents of this material. Those attracted to 'natural' cements due to its lower costs were singled out for their lack of knowledge and experience.[75] The higher price of Portland Cement in comparison to other cements in the early days, in fact, was often justified by this very idea of superiority: "[w]hen the builder is able to obtain a high-class constructive material at little more than the price of the inferior Belgian cement, he has less temptation to risk the loss which arises from the failure of the work" reads the note.[76]

Discussions on how older materials and methods of construction stood in the way of progress, especially in government-work, were also prevalent. The "laissez-faire attitude of officials in India", in one instance, was blamed for the late introduction of reinforced concrete in this region. These officials, an author argues, were biased towards timber, bricks, stone and lime

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[72] *The Everyday Uses of Portland Cement* (London: The Associated Portland Cement Manufacturers, 1913), p.6. [Emphasis original]

[73] Edwin A. R Trout, "Concrete Publications Ltd and Its Legacy to the Concrete Industry." *Construction History* 19 (2003): pp. 65-86.

[74] "Editorial Note." *Concrete and Constructional Engineering*, Vol 5, No. 1 (1910). It can be speculated that this differentiation arose at least partly from the fact that Britain imported large amounts of cement, most of which was natural cement from Belgium. The same note ends in the following way: "…whilst imports of cement have thus fallen off so substantially, it is gratifying to find that the exports of British cements have been well maintained during the present year." There might have been more than a simple concern for reliability and quality at play in this case.

[75] *Ibid.*

[76] *Ibid.*

“and no amount of reasoning as to recognized improvement in construction makes any impression” on them.[77]

From 1915, the British Standard Specification (BSS) was adopted in India. Under this act of codification, standards were set for various elements of the material, such as the fineness of grinding, residue on the mesh, specific gravity, chemical composition, tensile strength, setting time and soundness.[78] The scientization, standardization and abstraction of cement as a material is exemplified in the following tabular report the quality of Katni Portland Cement. Evidently, no other construction material from the preceding centuries were produced, tested or judged in such a n extremely compartmentalized manner.

[77] *Concrete and Constructional Engineering* Vol 12, No. 7 (1917), p. 388.
[78] Musgrave, *op. cit.,* p. 6.

12

GOVERNMENT TEST HOUSE.

ALIPORE, CALCUTTA.

REPORT.

BRITISH STANDARD TEST FOR PORTLAND CEMENT.

KATNI CEMENT COMPANY'S WORKS.

Name and Brand of Cement—Katni (Sample B).

(Selected by Superintendent, Government Test House, personally on his inspection.)

——	Results obtained.	Standard (1915).
1.—Fineness of Grinding—		
Residue on mesh 180 × 180 . .	18·5 per cent.	Not more than 14 per cent.
Do. 76 × 76 . .	0·8 „	„ „ 1 „
2.—Specific Gravity	3·11 „	Not less than 3·10. „
3.—Chemical Composition—		
Proportion of lime to silica and Alumina.	...	Between 2·85 and 2·0.
Insoluble residue . . .	...	Not more than 1·5 per cent.
Magnesia	...	„ „ 3·0 „
Sulphur calculated as SO_3 . .	...	„ „ 2·75 „
Total loss on ignition . . .	...	„ „ 3·0 „
4.—Tensile strength (neat)—		
7 days (average of 6 briquettes) lbs. $(=W_n)$.	653	Not less than 450 lbs.
28 days (average of 6 briquettes) lbs.	709	„ „ $W_n + \frac{40,000}{W_n} = 717$.
5.—Tensile strength (cement and sand)—		
7 days (average of 6 briquettes) lbs. (W_s).	361	Not less than 200 lbs.
28 days (average of 6 briquettes) lbs.	447	„ „ $W_s + \frac{10,000}{W_s} = 388$.
6.—Setting Time—		
Initial	118 mins.	Not less than 30 mins.
Final	Under 7 hrs.	Not more than 7 hrs.
Classification	Slow.	
7.—Soundness—		
Expansion after boiling 6 hours in LeChatelier Mould—		
(*a*) Cement aerated 24 hours .	1 mm.	Not more than 10 mm.
(*b*) Cement 7 days test (*a*) having failed.	...	Do. 5 mm.

Proportion water used in gauging –
(*a*) Neat briquettes . . . . 21 per cent.
(*b*) Cement and sand briquettes . . . . $8\frac{1}{4}$ „
Temperature during period of testing . . . . . . 85°—88°F.

Figure 3: British Standard Test of Katni Cement, *Musgrave's Report*, 1919, p.12.

The adoption of BSS resulted in some curious circumstances. Though cement could be manufactured in India, it had to comply with the specifications for slow-setting Portland Cement as in Britain. In 1920, the BSS added a clause that the tests on sand had to be done with the material acquired from a contractor in Leighton Buzzard, which necessitated the import of this sand by Indian manufacturers to achieve compliance with the standards.[79] Many structural and constructional issues also sprung from the attempt to directly apply British standards in

[79] Tappin, *op.cit.,* p 83.

India, due to the differences in temperature and labour skills: cement has an increased setting time in tropical climates and the unskilled nature of labour meant that the prescribed amount of concrete cover was often too little and left voids in the concrete.[80] In 1921, H. F. Davy wrote in *Times of India* pointing out the need for a revision of the standards, exploring the technical aspects of the relation between temperature and setting time.[81] Finally, in 1925, the BSS was revised with some alternations, one of which was the provision for testing in hot countries with temperatures running above 35 degrees Celsius.[82]

The result of such processes of standardization was that technical knowledge came to be based on a desire for 'best practices'. This pursuit of regularity, embodied in the testing and grading of cement and the formation and use of written instruments of quality control thus marked Portland Cement as distinct from other forms of cements. By the first half of the twentieth century, other cements ceased to be experimented with, and new protocols, standards and experimental facilities had been set in place to work solely with this new material.

This transformation occurred parallel to changes in the engineering profession itself. The nineteenth century, especially the inter-war period, had witnessed massive changes in the civil engineering cadre in general which, according to Ramnath, was professionalized, industrialized and Indianized to a great extent. New institutions analogous to the British Institution of Civil engineers were set in place, like as the Institute of Engineers (India) which was established in 1920 in Calcutta and whose total membership increased from 138 to 7308 between 1920 and 1950.[83] Civil Engineers, as Ramnath points out, used such organizations to define a role for themselves in the wider economic and technological field.[84]

These novel institutional spaces were inevitably used to promote the use of cement, as well as to evolve new methods of cement production and concrete technologies. Complementarily, cement and cement technologies became the fodder for the development of such spaces. By this

[80] Tappin, *op.cit.,* 83, 84.
[81] H. F. Davy, "Portland Cement: Its use in India, Need for Standard Specification", *Times of India,* 1 April 1921.
[82] *Times of India,* 13 November 1925
[83] Aparajith Ramnath, *The Birth of an Indian Profession: Engineers, Industry, and the State, 1900-47* (Delhi: Oxford University Press, 2017), p. 87.
[84] *Ibid.,* p. 68. The institution owed its existence largely to the report of the Indian Industrial Commission (1916-18), which proposed that the state should abandon its *laissez faire* policy and actively encourage industrialization. The report highlighted the government need for 'reliable scientific and technical advice' and guidance by reorganizing the government's scientific services and setting up professional societies. The IEI specifically "aimed to promote technical knowledge through paper discussions and publications; to play a role in engineering education through classes and examinations for working persons; to provide technical advice to the government on behalf of the engineering profession; and to act as a governing body to regulate the conduct of its members and 'promote efficiency and just and honourable dealing and … suppress malpractice in engineering.'" *Ibid.*

period, a cadre of technical experts had come to devote their careers to refining the techniques of concrete construction. These experts created a series of technical protocols to carry new knowledge about concrete to the building site. In other words, the standardization of cement and cement technology meant that this knowledge was now institutionalized.

In 1906, engineering graduates appearing for interview at the India Office had to be familiar with various materials used in building construction including wood and metal work; limes and cements; building with stone, brick, concrete. By the 1930s, however, engineers were required to possess thorough knowledge of the material composition, nature and methods of use of reinforced concrete. For instance, the examination for recruitment to the Engineering Services in India, required highly technical and specialized knowledge of applied mechanics and construction, with a specific focus on concrete. One had to be knowledgeable not only in the generic properties of 'limes and cements', but the highly technical elaborations of shear, bond and diagonal tension, the material nature of reinforced concrete, the evaluation and location of reinforcement, the design of simple and doubly reinforced beams and continuous beams, the theory and design of reinforced concrete columns and piles, the design of slab foundations, the design of simple cantilever and counterfort retaining walls, the equivalent moments of inertia for reinforced concrete sections and the theory of elastic deflections and outline of investigation of stresses in reinforced concrete arches. Additionally, candidates had to be familiar with the material properties of Portland Cement in particular, as well as the "Nature, uses, properties, advantages and disadvantages of reinforced concrete over other types of construction."[85]

By the early 1940s, concrete had come to claim an independent section of the examination on its own, where general principles, practical rules, theory, design, systems and economical methods of building bridges, tanks, towers etc. with concrete were to be studied. The material had become, by this period, integral to the profession of civil engineering. The repeated emphasis on understanding the material, its design, construction, the mechanical applications of it stands out for no other material warrants this level of attention. The university-trained expert, therefore, became the repository of knowledge on cement construction.

An important consequence of this process was that certain bodies of knowledge came to dominate the construction process at the building sites. Contrary to earlier forms of building where the knowledge of best construction practices and materials might have moved between generations or groups of practitioners, scientization and standardization brought the notion of

[85] Travancore State Gazette, Volume LXXI, Number 49, Part I (July 24 1934); p 14.

universal applicability to all sites, disseminating a formulaic norm for cement across different locales. In this new paradigm of construction based on expert technical knowledge of materials, different concerns about labour and skill emerged.

This process of specialization was reflected in the building site itself. Consider the construction of a five-storeyed residential building at Churchgate in Bombay in the 1930s: the building was designed by an architect, its execution planned by an engineer, the concrete work examined by a concrete specialist, building work was contracted by a construction company, the process of construction was overseen by two supervisors employed by the owner of the building and the contracting company who reported on the quality of the materials, labourers were supervised separately by a *muccadam,* and the materials were mixed, carried and applied by labourers contracted by the construction company.[86]

Questions of particular labour practices, further, endured in the technical narratives of engineers. As a consequence of cheap labour, mechanized mixers were rarely used in India in the early decades of the twentieth century, and concrete was mixed on the ground and carried to the site in small loads by workers. In 1915, E. A. W Phillips, a retired Superintending Engineer of the Burma Public Works Department, complained that though native Indian masons were "exceedingly clever" in using lime, they had difficulty using Portland Cement, and had to be specifically taught its use and "carefully watched besides, as they are stupidly stubborn."[87] He recalled instances where much "first-class material" was wasted because "the contractor grudged a trifling expenditure in keeping it wet". He also contended that concrete was laid almost dry, and was thoroughly rammed, instead of being slowly pounded into place, resulting in displacement of the cement.[88] Similarly, pointing to the difficulties of using Indian labour in concrete construction at a conference on the developments in the concrete industry at Olympia in 1922, an engineer argued that he faced considerable difficulty in engaging foremen in the region, since there were no ways to judge their qualifications.[89] New conceptualizations of cement and its technical control thus shaped what counted as authoritative knowledge at the building site, and what was 'retrograde' and 'unreliable'. A new organization of labour

[86] When this building collapsed in 1942 leading to the death of 59 of its inhabitants, it was precisely this separation and hierarchization of labour that legally obfuscated the responsibility for failure. See the articles on the Churchgate Reclamation building collapse in *Times of India,* between 1942 and 1945.
[87] *Concrete and Constructional Engineering,* Vol 10, No 8 (1915): p. 413.
[88] *Ibid.*
[89] *Concrete and Constructional Engineering,* Vol 17, No 5 (1922): p. 323.

emerged, where a small group of specialists trained in the technical properties of construction materials were rendered ‘superior’ to other workers.

In sum, Portland Cement had emerged as a 'modern' material not only in the rhetoric of its advocates, but also in the sense that its production and application had become standardized, regularized, mechanized and scientized and tethered to the notion of calculability and universal applicability.

A ‘Modern’ Material: Resistances and Divergent Meanings

In 1935, Ramkinkar Baij, who has come to be considered one of the pioneers of modern Indian sculpture, built his first cement figure titled *Sujatha*. Baij did not merely chose cement as his medium because it could survive the extreme temperatures and rainfall in Bengal or because it was cheaper than stone and plaster of paris.[90] For him, it was a material that best allowed the articulation of a distinct modern moment that he desired to capture in his sculptures. To Baij, cement symbolized the possibilities of breaking out of a cultural cocoon to embrace what him and the other Santiniketan artists considered a ‘modern’, trans-national, formal language. This 'contextual' modernism, argues art historian R. Sivakumar, was a “critical re-engagement with the foundational aspects of art necessitated by changes in one’s unique historical position.”[91] In 1938, Baij created *Santhal Family,* a sculpture that has been described as a representation of the “dynamism of traditional Bengal at the time of industrialisation”.[92] And what better material could Baij have chosen to engage with this historical position?

However, not all cement sculptures received the acclaim that Baij's did. In early twentieth century Kerala, when cement statues of social reformer Sree Narayana Guru were installed, some upper-caste factions began derogatorily calling him ‘Cement Nanu’. The material and aesthetic qualities of cement, which were considered inferior to stone and wood, were conflated with social hierarchies. Cement, for them, represented the new and the egalitarian, and therefore something base.

[90] “Remembering Ramkinkar Baij: The vanguard of modern Indian sculpture”, *The Telegraph,* 2 August 2019, https://www.telegraphindia.com/culture/people/remembering-ramkinkar-baij-the-vanguard-of-modern-indian-sculpture/cid/1695703

[91] R. Sivakumar and Parvez Kabir, “All the Shared Experiences of the Lived World,” *Humanities Underground,* 30 December 2013.

[92] Vandana Kalra, “Five landmark works by India’s foremost sculptor Ramkinkar Baij,” *The Indian Express,* 30 May 2020, https://indianexpress.com/article/lifestyle/art-and-culture/five-landmark-works-by-india-foremost-sculptor-ramkinkar-baij-6434287/

The materiality of modern cement was often contrasted with older materials in the emerging economic philosophies of the early twentieth century. In his *Economy of Permanence,* for example, J. C Kumarappa considered cement an essentially lifeless material:

> An expert cement concrete architect from New York will stand aghast at the valuable time lost at Ellora in carving out three storeyed temples out of living rock with elaborately chiselled figures adorning the pillars etc. He will be quite unable to appreciate the great knowledge of geology which enabled the ancients to select those rocks as flawless for such masterpieces of sculpture, and the deep devotion that has gone into the making of them.[93]

In his economic thinking, Kumarappa distinctly attributed cement to a "reservoir economy" where material flows are driven by limited supply of its minerals, coal or petroleum. Unlike timber, cotton or water which were growable or inexhaustible, and thus tied to a "current economy", cement was part of a "predatory" order that took from nature what it could not return.[94] He wrote,

> A mud-hut with thatches for the roof belongs to current economy. Buildings of cement and concrete belong to the reservoir economy. Current economy is permanent because it does not lead to competition which will result in violence and destruction, while reservoir economy is not permanent.[95]

Yet, this moral characterization of the natural order did not preclude, even for Kumarappa, the use of cement altogether. Cement could be used, for instance, to build *pucca* cement godowns in big cities for grain storage, he proposed.[96]

The impossibility of disregarding cement was acknowledged, in a similarly contradictory way, by architects. In 1945, acclaimed Indian architect Laxman Mahadeo Chitale expressed his indignation over the “standards of modernism” that the machine age had imposed on our minds.[97] “There is every danger”, he said, “of Indian architecture, after retaining its unique individuality for over five thousand years, now being merged and absorbed into the present craze for modernism”. However, India also needed to

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[93] J. C Kumarappa, *The Economy of Permanence: A Quest for a Social Order Based on Non-violence* (Wardha, CP: All India Village Industries Association, 1946), p. 43.
[94] Venu Madhav Govindu, and Deepak Malghan, “Building a Creative Freedom: J C Kumarappa and His Economic Philosophy,” *Economic and Political Weekly* 40, no. 52 (2005): pp. 5477-5485.
[95] J. C Kumarappa, *Gandhian Economic Thought* (Bombay: Vora, 1951), p. 10.
[96] Kumarappa, *The Economy of Permanence, op. cit.,* pp. 121-122.
[97] L. M. Chitale was the architect of prominent buildings such as the LIC building in Chennai, the High Court of Kerala in Kochi and the RBI building in Nagpur.

> take her place in the present day world of industrialism…An important aspect of the future of India is the planning and replanning of cities…[and] new requirements seek new methods and new materials. Cement has opened up immense possibilities for the future. Its use for evolving styles and expressions within our ancient monuments needs careful research.[98]

In sum, the very identity of Portland Cement as a singular, standardized, 'modern' material, which industrial experts painstakingly manufactured for it, made it unpalatable for those who opposed the tenets of that modernity. Nevertheless, as we have seen, even those who shunned it could not help but acknowledge the material powers of this “dullest of all dull but useful materials” which would shape their future built world.

…

This chapter endeavoured to trace how Portland Cement emerged as a new material and how the Indian cement industry evolved in the first half of the twentieth century. It highlighted how the material was fashioned through processes of standardization and codification alongside industrial rhetoric. Portland Cement was increasingly presented as *the* material to build with, associating it with notions of progress and modernity. This markedly 'new' material and its technology were placed at the core of the story of human evolution itself. The “epoch-making” age of cement was seen as a stage in human progress, a marker of how well humankind could manipulate the “treasures of the earth”. India’s colonial ‘modern’ cemented built environment, further, was separated from earlier architectural forms such as those, for instance, under the Mughals.[99]

Over the course of the former half of the twentieth century Portland Cement not only became a marker of a discrete present, but also rapidly came to occupy visions of the future. The next chapter explores some of these visions more closely, through three infrastructural contexts from this period.

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[98] L. M. Chitale, "Architecture in India,” *Indian Concrete Journal* (February 1945): pp. 27-28.
[99] “The Concrete Age: A Vision of the Future,” *Times of India*, 16 Mar 1923: 19.

Chapter Three

Materializing the Future: Concrete Infrastructures c. 1900s-1940s

As Timothy Mitchell suggests in *Rule of Experts*, the agents, temporalities, spatial scales and exchanges involved in technological, economic and political processes are too often analyzed as separate. What we ought to turn our attention to, he writes, are the interactions between them:

> [s]ocial science is always founded upon a categorical distinction between the ideality of human intentions and purposes and the object world upon which these work…[there] is little room to examine the ways they emerge together in a variety of combinations, or how so-called human agency draws its force by attempting to divert or attach itself to other kinds of energy or logic.[1]

This chapter is an exploration of how material technologies, infrastructures and industrial forces 'emerged together' in early twentieth century India, and how certain schemes attached themselves to the 'logic' of cement and concrete. Studies of infrastructure in colonial India often focus on those projects which reveal the logics of colonial rule. For instance, irrigation systems, railways and telegraph networks are considered illustrative of the material expressions of colonial power or the economic rationality of capitalist development.[2] There is, however, an immense potential in reimagining the category of infrastructure more broadly as a "socio-material and technical assemblage of practices and institutions, which enabled new forms of governance and claim making, circulation, appropriation and dispossession".[3]

This chapter attempts to reconsider the infrastructural terrains of late-colonial India along this line, bringing into attention not only a project initiated by the colonial state, but also other visions of a concrete built environment in this period. The case studies considered include the construction of the first entirely concrete dam at Mettur by the Madras government in the 1920s, the cement industry's drive to build concrete villages for India's post-war development in the 1940s, and the crusade for concrete roads in India between the 1920s and 1940s. In one way or

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[1] Timothy Mitchell. *Rule of Experts: Egypt, Techno-politics, Modernity*. (Berkeley, CA: University of California Press, 2012), p. 28.
[2] Timothy Mitchell, "Introduction: Life of Infrastructure," *Comparative Studies of South Asia, Africa, and the Middle East* 34, no. 3 (2014): pp. 437-439.
[3] Aditya Ramesh Aditya and Vidhya Raveendranathan, "Infrastructure and Public Works in Colonial India: Towards a Conceptual History," *History Compass* (2020): p.2

another, all three projects did not materialize in the ways experts intended. These early 'failures' are revelatory of both the contingencies and hybridities that continued to challenge the new paradigm of concrete construction, as well as the place which this material came to occupy in divergent visions of the future.

"Empire's Biggest Dam": the Failed Visions of Concrete at Mettur

The development of an Indian cement industry in tandem with processes of singularization and standardization in the inter-war period meant that, by the late 1920s, largescale use of cement and concrete in dam construction was becoming a real possibility. The story of the construction of the Mettur Dam is illustrative of the various considerations, difficulties and adaptations related to the early building of such dams. It reveals how human expertise on cement and concrete technologies was ultimately circumscribed by material conditions on the ground.

Built across the Kaveri in Tamil Nadu by 1934, the Mettur dam was considered one of the largest dams in India at the time of its construction. The Mettur scheme was sanctioned in 1924, and a revised estimate was approved in 1929, when the work began under engineer C. T. Mullings of the Madras PWD.[4] The original scheme, put forward much earlier, had proposed that the dam be built like other dams of the time, in rough stone masonry laid in lime mortar. Soon after the construction of the dam began in 1925, however, the government felt that a dam of cyclopean masonry in *surkhi* mortar would not be safe because the resultant stress, especially on the lower part of the dam, could be very great.[5] After consultation with the Chief Engineers for Irrigation in the United Provinces, Central Provinces and Bombay, the Government of Madras ultimately decided to construct the dam entirely in Portland Cement-concrete.

This decision generated numerous public discussions regarding the benefits of cost, speed, and safety in building with cement-concrete. A newspaper article from 1929 which challenged the criticisms towards using cement-concrete to construct the dam, argued that though a concrete dam would cost more than a masonry dam, its quicker completion would actually

[4] "The Mettur Project Continued," *Times of India*, Aug 1934: p. 14.
[5] *Surkhi*, or brick-dust, is often used as a substitute for sand in mortar.

warrant a financial advantage of more than one hundred and fifty lakh rupees. The dam in cyclopean masonry using lime was estimated to cost one hundred and forty-eight lakhs, whereas a cement concrete dam would cost thirty-two lakhs more. However, it was argued that the proposed concrete dam was smaller than the masonry dam, and that consequently, quicker construction would help recover the and the extra cost of 24 lakhs in the form of revenue. In seventeen years after completion, the cement dam was predicted to generate 180 lakhs of additional net revenue.[6]

The opponents of the scheme were also warned about the dangers of a masonry dam:

> Many of the advocates of a masonry dam who are residents in these districts should bear in mind that they will have to be in perpetual horror of being washed out into the sea, if they want their pet proposal to be carried into practice by the government. [7]

The size of the dam attracted much attention as well, and was connected to the question of safety. The dam was proposed to be both bigger and stronger than the Sennar dam which had recently been built cross the Blue Nile in Egypt.[8] "The Mettur reservoir has a capacity only exceeded by two other reservoirs in the world and the flood that would result from its failure would be disaster comparable with the Great War", reads an article from 1928.[9] In spite of continuing public debates over the value of building with concrete, construction began in the late 1920s.

In 1929, it was estimated that 1,85,000 tons of cement and 8,50,000 tons of sand would be required for constructing this massive structure. It was proposed that Indian Portland Cement produced by the Shahabad Cement factory (which was closest to Mettur), considered fully up to the latest British Standard Specification, would be used. PWD engineers countered those who critiqued the high costs by stating that "[c]ritics have to remember that Shahabad cement is an Indian cement, manufactured in India with the aid of Indian capital and Indian labour and they should rejoice over the wise decision of the government from a patriotic as well as from an economic point of view".[10]

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[6] By 1929, the impact of the Great Depression on Indian agriculture was unavoidable and the crash in prices, which had been delayed till then by the withholding of stocks, set in. The decision to make construction swifter could have also been shaped by this context.
[7] "The Mettur Dam Controversy: Reasons for Concrete Construction," *Times of India*, 29 Aug 1929: p. 13.
[8] "Mettur Dam: Estimated Cost," *Times of India,* 30 May 1929: 16.
[9] "Construction of Mettur Dam: Preparations for a Gigantic Scheme," *Times of India*, 23 Feb 1928: p. 16.
[10] "The Mettur Dam Controversy," *op cit.*

In the final analysis, the decision to build the dam completely in concrete resulted in the development of a novel ecosystem of concrete construction. To begin with, the massive material requirements to meet the promised standards of safety and speed necessitated mechanization. The engineers proposed to install a specially designed plant suited to local conditions capable of an outturn of 3000 tons of concrete daily. The government also accepted a proposal put forward by the Superintendent Engineer for machinery W. P. Roberts, to spend about fifty lakh rupees on machinery alone. For the supply of stone, extensive quarrying with modern technologies commenced by means of specially designed quarrying plants on both flanks, which were to be linked through ¼ mile broad gauge railway lines for a travelling steam crane to move.

The most important part of the mechanized construction process was the electrically driven travelling concrete placing machinery. The engineers at the site had come to the conclusion that neither ropeways nor cableways were suitable for the work of placing concrete. Therefore, two sets of travelling hoisting towers arranged to work a radius of a hundred and fifty feet to command the full height of the dam were set up, with 20-inch chuting systems and their own storage bins and concrete mixers. [11]

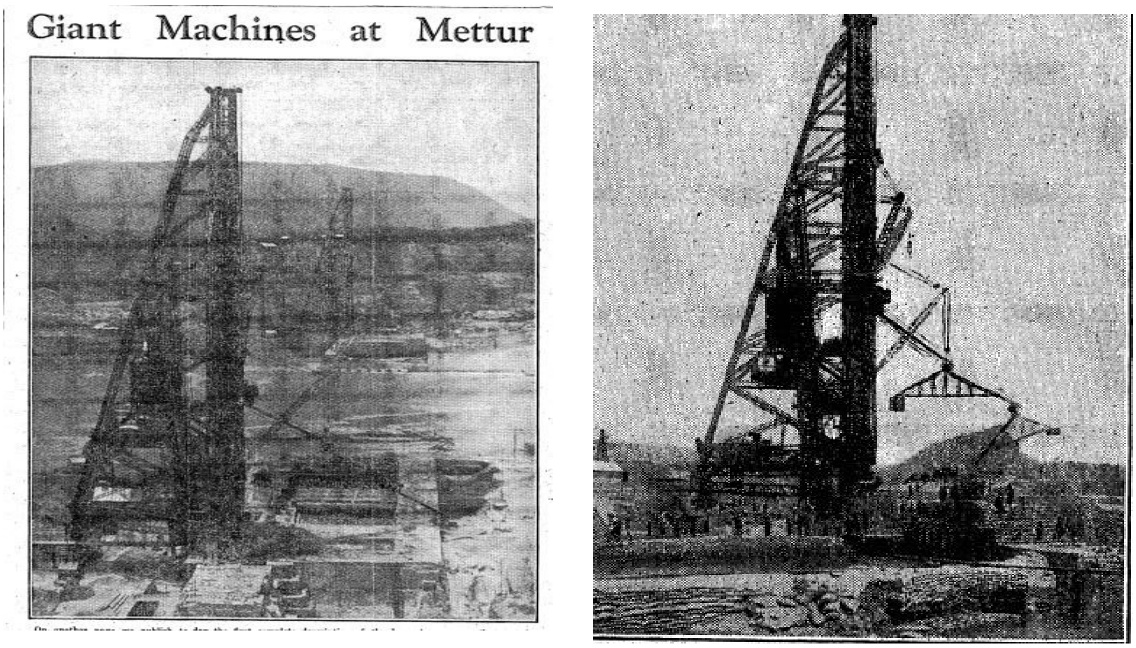

Figure 4: Concrete placing machinery at Mettur Dam, *Times of India,* August 1934.

[11] "Construction of Mettur Dam," *op.* cit. The machines were supposedly capable of preparing and placing 120-160 tons of concrete per hour. In this way, 126 feet length of the dam was to be concreted without any movement of the main machine.

However, once the actual process of building commenced, this concreting machine proved far less efficient than originally expected. The towers and crushers which fed into the machines were purchased to speed up construction at a total cost of forty-nine lakhs. However, the towers could not work to their maximum capacity (three thousand tons per day of twelve hours to cover entire length of 5300 ft). In addition, they could not function in reaches up to 620 ft. or between 3900 ft. to 5300 ft. because the cost of the construction needed to enable their travel to these extents was disproportionate to the outturn: the average outturn was a mere 900 tons per day. Further, percolation tests conducted during the latter months of 1929 revealed masonry to be more impervious than concrete, and therefore better suited for the front face of the dam. Once later developments suggested that it would have been preferable to build the dam with more rough stone masonry and less cement-concrete than provided in the original design, the dam was ultimately built as a hybrid of rough stone masonry and cement concrete, the latter accounting for only about a third of the cubic contents of the dam.

In this modified version, concrete was placed between walls of rough stone masonry in some parts, and only rough stone masonry was used in other reaches, as it had been found possible to obtain an average outturn of over 4000 tons a day with masonry and concrete together. Masonry work was thus proceeding at a pace greater than the promised maximum output of the special machinery.[12] Similarly, to economize on cement, 20% of the mix was to be made of *surkhi* made from local bricks ground in a special disintegrator, as had been suggested in the original plan.[13] The grand imaginations behind the project could not be fully realized in the actual process of construction.

Writing about the Aswan Dam in Egypt, Mitchell recounts the words of a European writer, who, on his visit to the dam wrote that a "mighty element had been tamed by human ingenuity so that the desert should bring forth fruit…"[14] A similar language was used to describe the construction site of the Mettur Dam, which was considered

> the venue that will, in time, be one of the triumphs of man's skill in applying the potential forces of nature to his own needs. For it is here that the great Mettur dam is being built to confine the waters of Cauvery and to regulate the discharge for irrigation purposes lower down the river.[15]

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[12] "New Facts about the Mettur Dam: More Stone Being Used," *Times of India*, 16 June 1932.
[13] "The Mettur Dam Project Continued," *op cit.*
[14] Mitchell, *op. cit., Rule of Experts,* p. 35.
[15] "Mettur Dam: Estimated Cost," *op cit.*

Another visitor marvelled at the size of the project in 1929, remarking that "the layman is at once struck by the immensity of the project on which all modern engineering ingenuity is being expended." [16] As Mitchell argues, the building of such dams were important moments in the historical construction of 'nature' as opposed to the 'human'. The tremendous scale of these structures and the discussions surrounding their construction, safety and impact fed the notion of human ingenuity and expertise capable of dominating the forces of nature. As he so succinctly puts, "[i]n manufacturing the dam, the engineers also manufactured nature."[17]

The concentration of concrete engineering at the site of the dam necessitated a parallel concentration of capital, and therefore a number of proposals, plans, reports and newspaper articles on the economic and constructional calculations and descriptions of the building of the dam. This reorganization of calculation, description and knowledge concentrating exclusively on the dam, was a process through which the world was reduced to nature on the one side and human calculation and expertise on the other. Mitchell highlights how life "was now to be increasingly resolved into this binary arrangement, rendering up a simple, dualistic world of nature versus science, material reality versus human ingenuity, stonework versus blueprints, objects versus ideas."[18]

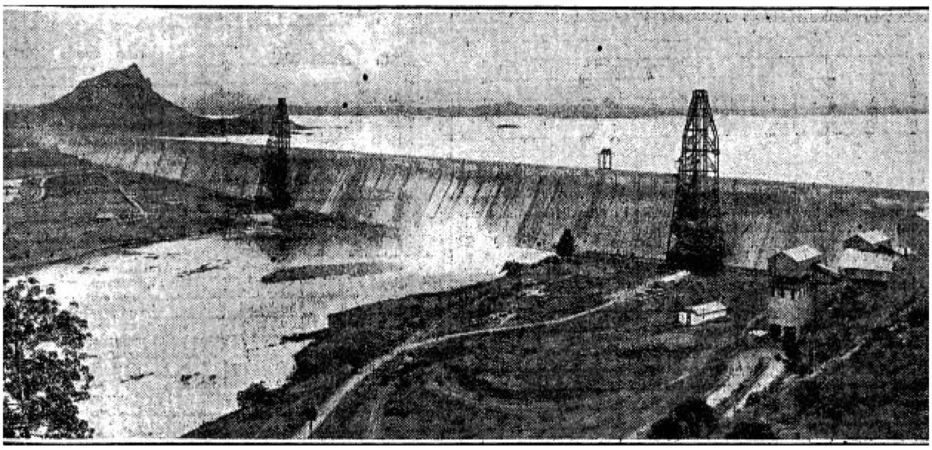

Figure 5: Mettur Dam: Overview of construction site, *Times of India,* August 1934.

[16] "The Mettur Dam: One of the Biggest in the World," *Times of India*, 23 Oct 1930: p. 7.
[17] Mitchell, *op. cit., Rule of Experts,* pp. 34-35.
[18] *Ibid.,* p. 36.

However, if one considers the actual process of construction, this manufactured division between human agency and material or natural forces breaks down. The final infrastructural entity was vastly different from its estimated version, as the experts could not foresee the numerous contingencies of construction. The calculations were often far from accurate and the ultimate structure was a product of many revisions, uncertainties, delays and conflicts. Cement-concrete and its ancillary equipment, though portrayed as material technologies subject to human expertise and planning, did not accept this 'secondary role', and "there were always certain effects that went beyond the calculations, certain forces that exceeded human intention. Scientific expertise …[was] produced out of this tension".[19]

Concrete did not direct the engineer's work as a performed intelligence. Rather, the dam itself constituted the technology of concrete. This is not to imply that concrete worked against human expertise as an 'obstacle to technical progress', but rather to acknowledge that, "[p]lans, intentions, scientific expertise, techno-power, and surplus value were created in combination with these other forces or elements."[20] The technology of concrete infrastructures, in other words, emerged from the process of construction itself. This materialized technology was far from totalized. It assimilated delays, failures and hybridities that the infrastructural visions did not anticipate.

With cement increasingly being branded as the pinnacle of modern construction and human expertise, it is not surprising then, that in 1931, a series of photographs of the Mettur project were sent to the India Office for publicity in the United States, as emblems of the "progress and improvement of India under the British."[21] It was the "Empire's biggest dam", as newspapers across the world repeatedly referred to it in the 1930s. Just as rhetoric around cement seeped into the state's activities, the language of empire co-opted symbolisms of cement for itself. In 1927, addressing graduates at the Calcutta University Convocation, Lord Lytton implored that "India...had a very ancient civilization behind her but she had also a great future before her...What India needed was not dynamite, but cement; not brickbats, but walls, men and women who live for her rather than die for her."[22] To the colonial state, cement had come to signify its own endurance in direct and indirect ways.

[19] *Ibid.,* p. 38.
[20] *Ibid.,* p. 52.
[21] Home Political, Progs. Nos. 35-22, 1931, National Archives of India, New Delhi.
[22] "Not Dynamite but Cement: India Needs," *Times of India,* 21 February 1927.

However, as the case of the Mettur Dam reveals, the early material locus of this signification manifested in unfulfilling ways. In spite of such early 'failures', the material continued to be used for dam construction in the subsequent decades, often for the alleged benefits of speed and safety. Indeed, concrete and its varieties would ultimately become the nucleus of the new paradigm of multi-purpose projects, though this transition was far from smooth. On the other hand, the next two ventures discussed in this chapter throw light on the prolonged absence of cement and concrete from certain spheres of the built environment.

“Villages of Tomorrow”: an Industrial Quest for a Concrete Future

The British colonial state had been the largest consumer of Indian manufactured cement since the inception of the industry. Though this monopsony had allowed it to dictate the price of cement indirectly in the beginning, with the emergence of conglomerated manufacturers the industry was gaining a better position vis-a-vis the state. With the advent of the Second World War, cement became a highly coveted material.[23] In 1942, the Government instituted a control of the cement industry under the Defence of India Rules, stipulating that 90% of the total output ought to be supplied under the quote of the Engineer-in-Chief, and the rest be supplied under the Honorary Cement Adviser’s civilian quota, the requirements of the Provincial Government being considered under the latter.[24] By 1944, 80% of the total output was being directed toward the demands of war.

[23] “Cement and War”, *Indian Concrete Journal* (June 1945): p. 74.
[24] P. J. Thomas, *Development of Industries for War Supplies*, Delhi: Government of India, 1944, pp. 62-63; and Amiya Kumar Bagchi, *Private Investment in India, 1900-1939* (Cambridge: Cambridge University Press, 2008), p. 358.

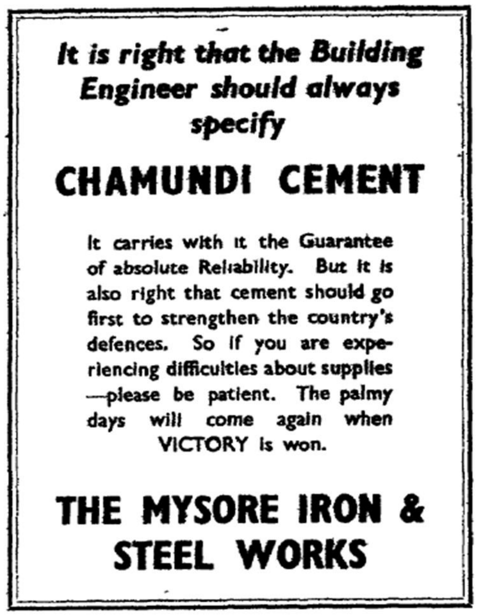

Figure 6: An appeal for patience: Advertisement for Chamundi Cement, *Indian Concrete Journal* (February 1945)

These measures gave a tremendous impetus to the cement industry.[25] As profits soared, larger companies acquired licenses, strengthened their cartels, and even acquisitioned newer companies.[26] Though Indian industrialists were rebuffed by the Government's unwillingness to include the industry in managing the war economy, they remained sympathetic to the Allied forces.

By the mid-1940s, they were faced with political choices which they had to reconcile with their economic imperatives. In 1944, prominent businessmen circulated what has come to be known as the Bombay Plan, which "spelled out the promise of a close partnership between private enterprise and the emerging Indian state."[27] The optimism of the businessmen about the economic future of the country and the role of private enterprise in it, owing partially to the strengthened position of the industries in the war years, was reflected in the Bombay plan.

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[25] Thomas, *Ibid.,* p..63. As the military offtake of cement between 1938-39 and 1944-45 increased from 1,23,000 tons to 12,66,000 tons (peaking at 19,70,000 tons in the period between 1942-43), the industrial production of cement increased from 15,12,000 tons in 1938-39 to 21,51,000 tons in 1945-46. The quantity available for civil consumption, on the other hand, fell from 14,15,000 tons in 1938-39 to 2,19,000 tons in 1942-43, before rising up to 7,78,000 in 1944-45, and then back to 19,75,000 tons in 1945-46. See: *Statistics Relating to India's War Effort,* Delhi: Department of Commerce, Government of India, 1947, pp. 28, 18 and 31.

[26] Yasmin Khan, *India at War: The Subcontinent and the Second World War* (Oxford: Oxford University Press, 2015), p. 85. This was true not only for big businesses, but also the princely states. For instance, cities like Bangalore, Jaipur and Rampur witnessed the rise of new factories producing materials for the war, resulting in a boom. Porbander and Hyderabad were important suppliers of cement to the British. See p. 138.

[27] Medha Kudaisya, ""The Promise of Partnership": Indian Business, the State and the Bombay Plan of 1944," *Business History Review* 88, no. 1 (2014): p. 98. Those involved in drafting the plan included J.R.D Tata, G.D Birla and Purushoththamdas Thakurdas.

Apart from a phased programme for industrialization, the Plan foregrounded aims such as higher living standards for the population through investing in education, agriculture, communication, health, housing and higher education.[28]

Yet, the materialization of this plan in terms of the cement and concrete economy reveals a more pragmatic approach on the part of the industrialists. As many scholars have pointed out, the businessmen, in this period, attempted to straddle the middle ground between imperial and nationalist forces, adopting a practical approach.[29] While cement clearly had an important role in the 'national' future imagined by businessmen and engineers, their rhetoric in this period remained ambiguous on which 'state' they hoped to collaborate with. They advocated the building of material infrastructures which was a goal exclusive neither to the National Planning Committee nor the British colonial state. They championed causes of all variety- community development, village improvement, planning and reconstruction- supporting at different times both the central and provincial governments.

Cement was to be of immense national importance as one of the few materials which could enter into and assist in almost every scheme of rehabilitation and development; and the "cement industry of India [was] fully alive to the immense demands that will be made on it when a world at peace resumes its normal avocations."[30] Throughout the years of the war, cement manufacturers weaved their rhetoric into the larger discussions on village improvement and upliftment as part of post-war planning, which were being propagated by both the colonial and nationalist quarters. The idea of 'village uplift' as it emerged in the works of the Indian cement manufacturers, for example, took inspiration more directly from colonial visions of remaking Indian rural economy.[31] In any case, there were considerable continuations between the colonial conception of rural India and certain nationalist imaginings, especially the Nehruvian understanding of the village as a site of backwardness.[32]

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[28] *Ibid.,* pp. 99, 115, 123; and Amal Sanyal, "The Curious Case of the Bombay Plan," *Contemporary Issues and Ideas in Social Sciences,* (June 2010).
[29] *Ibid.,* p 85.
[30] "Cement and War," *op. cit.,* p.74.
[31] Albert Frederic Lucas Brayne, Malcolm Lord. Hailey, and G. F. De Sir. Montmorency, *The Remaking of Village India, Being the Second Edition of 'Village Uplift in India* (Bombay: Humphrey Milford, 1929). This work is cited multiple times across the issues of the *Indian Concrete Journal* as a template for the development of rural economy through a focus on education, health and administration.
[32] Surinder Jodhka, "Nation and Village: Images of Rural India in Gandhi, Nehru and Ambedkar," *Economic and Political Weekly* 37, no. 32 (2002): pp. 343-353 and Subir Sinha, "Lineages of the Developmentalist State: Transnationality and Village India, 1900-1965," *Comparative Studies in Society and History* 50, no. 1 (2008): pp. 57-90.

Planning, however, was not merely meant to institute a mechanized and regimented life. In so far as it represented the *zeitgeist* of an era, as Mulk Raj Anand wrote in 1946, "planning is like dreaming- dreaming of a new world."[33] In the 1940s, the Concrete Association of India and the Cement Marketing Company of India ventured to materialize this new world by carrying out small-scale 'improvements' in various villages scattered across the country.[34]

In 1945, the Associated Cement Company completed its first community development venture in Virar, located thirty-eight miles from Bombay. The project was presented as "a practical demonstration" of village improvement with cement, to signify the "important role that cement is bound to play in post-war rural planning."[35] At this site, various items were built as model improvements, such as a " new village house incorporating concrete features as roofing, plastering, flooring, jalli work, ventilators and sun-shades", a grain silo, an approach-way, a drinking fountain, creteways, a track for bicycles and single-wheeled hand carts and bullock carts, a platform to the village market, a travelers' rest-house, surface drains and 'Athams' (road-side platforms for headloads), lamp standards and cycle parking blocks.[36]

Figure 7: A Concrete Grain Silo: Rural India and Cement, *Marg*: *A Magazine of Architecture and Art,* Vol 1, No. 4 (1947): p.44

[33] Mulk Raj Anand, "Planning and Dreaming", *Marg*: *A Magazine of Architecture and Art,* Vol 1, No. 1 (1946): p. 4.
[34] "Rural India and Cement", *Marg*: *A Magazine of Architecture and Art,* Vol 1, No. 4 (1947): p. 44.
[35] "Village Improvement in Virar", *Indian Concrete Journal* (February 1945): p. 13.
[36] *Ibid.*

At the inauguration ceremony of this site, Mr. T. R. S Kynnersley, the Chief Engineer of the Concrete Association of India, indicated that

> although planning was the duty of Government, in these days of scarcity of practically everything, it seemed right to help the Government and the people to understand something of the village structures in which cement played a prominent part. The work they had done was meant to be of permanent use to villagers in Virar, as well as to serve as an example to other villages. [37]

Mr. Collins, adviser to the Governor of Bombay, responded to Kynnersley's words in his inaugural address, making particular care to emphasize governmental interest in post-war rural reconstruction:

> I regard this experiment as of particular importance when the minds of Government and the public are turned towards a better and more prosperous India after the war, and when, with what we now know will be an early and happy conclusion of the war, Government is engaged in planning post-war development. I regard Mr Kynnersley and his Association as forerunners of progress who have seen ahead of Government and the public…[38]

He then emphasized the centrality of villages to the Bombay Government's post-war plan, drawing attention to the proposal to name key villages in concentrated areas as "Centres of Civilization", building not only schools, dispensaries, *chavdies* and village clubs, but also houses for returned soldiers, all of which "must be modern and must present an attractive appearance and yet must not cost more than the tax-payer can afford...It was clear enough that cement must be the main material for village buildings of the future," In spite of this optimism, Mr. Collins ended his speech on a cautious note:

> I am afraid that even Mr. Kynnersley, conjurer as he may be, will not be able to produce hidden supplies of that material...nor do I expect that he will be able at this stage to guarantee the future price at a figure to suit the tax-payer's pocket. That will, however, not prevent us from being cement-minded.[39]

But Kynnersley's idea of the rural, influenced by colonial notions of the village, was different. To him, the village was a centre of backwardness, and he continued to assert that the vast majority of villagers existed at a very low subsistence level and that engineers were the very

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[37] *Ibid.* It is interesting to note that he was addressing an audience consisting of Mr. G. F. S Collings, CSI, CIE, OBE, ICS, Adviser to HE the Governor of Bombay, Sir Charles Bristow, Kt, CIE, ICS, Adviser to HE the Governor of Bombay, Mr G V Bedekar, Collector of Thana, Mr H G Vartak, Chairman of the Virar Village Panchayat and other well-known Municipal and PWD officials, and District Local Board members.
[38] *Ibid.*
[39] *Ibid.,* p. 14.

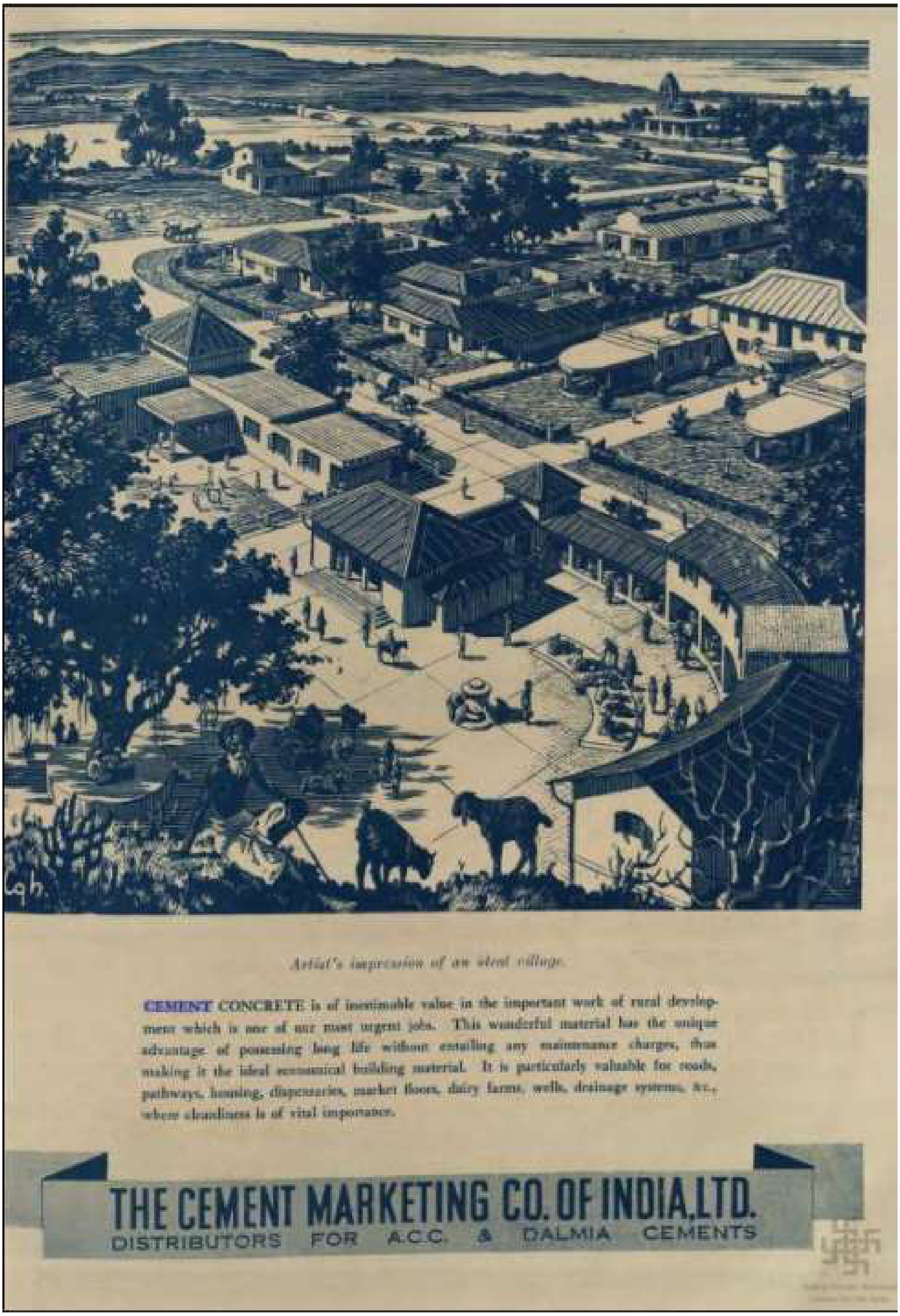

Figure 8: Artist's impression of an ideal village, *Marg*, Vol 1, No. 1 (January 1947).

people who ought to be the first to give assistance to them.[40] Cement was therefore considered particularly suitable for "villagers" because it was economical, and had a lower maintenance cost. "It is often said that a poor villager cannot afford to use cement, actually he cannot afford to do without it", he argued.[41]

In its vision of a concrete future, the industry also envisioned certain roles for citizens. Borrowing from Brayne's perspective, Kynnersley understood the "average Indian soldier and villager [as] one of the foremost champions of the cause of the demobilised man", and that before any economic planning could take place, it was necessary to realize their freedom from hunger, debt, disease, ignorance and boredom, among other debilitating factors. Accordingly, The Concrete Association of India devised a plan to combine this vision with cement. As part of the demobilization initiatives in the aftermath of the war, it hoped to train the returning soldiers in elements of concrete work and the methods of using cement correctly. Six or seven centres were to be formed, each training a batch of around twenty men every six months, who would then disseminate this knowledge to tens of thousands more.[42]

The women, on the other hand, had a different role in this project:

> While we cannot aspire to educate many Indian women in the technicalities of cement work, we hope to interest them in the need for better and cleaner houses. Cement is the recognized material with which labour saving homes can be built. There is nothing so easy to keep clean as a concrete slab...Just as cement concrete has been used in war as a means of fighting the enemy, so it has to be used in the years to come to fight the more lasting and powerful enemies of dirt and disease. [43]

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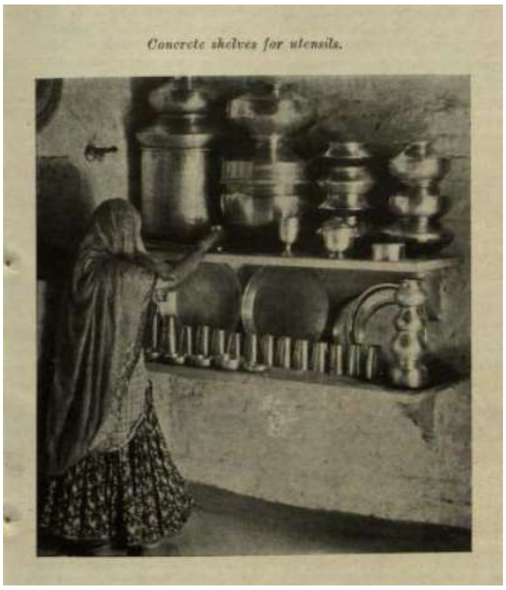
[40] "Editorial: Village Development.", *Indian Concrete Journal* (May 1945): p. 57.
[41] "Editorial", *Indian Concrete Journal* (July1945): p. 93.
[42] *Ibid.,* p. 1.
[43] *Ibid.*



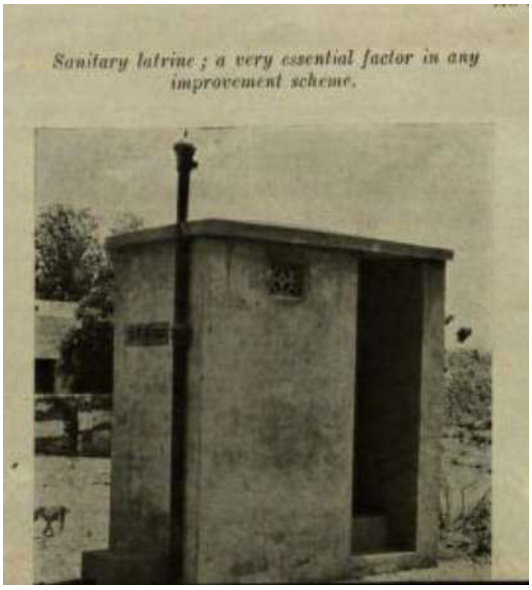


Figure 9: 'Concrete Shelves for Utensils' and 'Sanitary Latrine': Rural India and Cement, *Marg,* Vol 1, No. 4 (1947): p. 44

Among its many other publications, ACC's widely circulated booklet *Our Villages of Tomorrow: How Shall we Build Them* - first published in 1932 and reprinted in 1949 - would come to shape the public imagination of rural development in the 1950s.[44] Earlier ideas about planning and training were distinctly consolidated in this publication. ACC's vision was underpinned, to begin with, by the desire to erase the visual evidence of poverty. This manifested in their designs, for instance, as schemes for rural sanitation. Secondly, the solution to the problem of 'unskilled' village labour was to be their incorporation into the construction process under the rubric of 'self-help'. Thirdly, the plans evolved to include public institutions which could impart a “civic sense” among the villagers, which was presumed absent. For instance, apart from a central village hall or centre, a village cinema was incorporated into the scheme. [45]

[44] Farhan Karim, “Negotiating a New Vernacular Subjecthood for India, 1914-54: Jacquline Tyrwhitt, Patrick Geddes and the Anti-utopian Turn”, *South Asia Journal for Culture,* Vo. 5 and 6 (2018): p. 58.
[45] Farhan Karim, *Of Greater Dignity than Riches: Austerity and Housing Design in India* (Pittsburgh: University of Pittsburgh Press, 2019), p. 156- 159.This volume is an excellent exposition of the evolution of the prototypes of the 'ideal village' and housing schemes against the backdrop of developmentalist schemes and the larger discourse on 'austerity'. This book examines how a 'modernism for the poor' was inscribed into the plans for rural development.

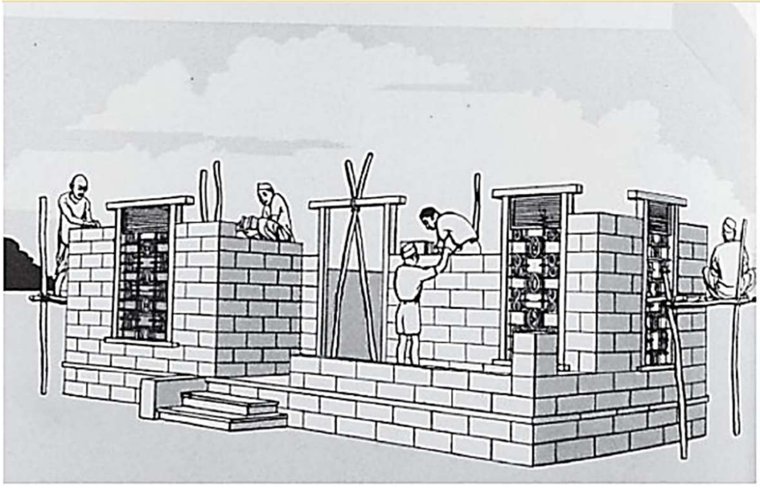


Figure 10: 'Self- help' and construction of rural housing*, ACC, Our Villages of Tomorrow: How Shall we Build Them* (Bombay: Associated Cement Companies, 1932, reprint 1949).

In the late 1940s, thus, a distinct vision of a rural built environment erected in cement and concrete had taken shape. However, the scarcity of trained labour continued to be an obstacle to concrete rural development schemes, even though the material itself was often easily available. At a demonstration farm centre completed in 1946 at Vanhar, Punjab as part of the resettlement training for Indian troops in the demobilization period, for instance, the local building material of limestone was employed with mud and dung plastering. The use of concrete was limited to two standard pre-cast concrete units which was made by unskilled labour.[46] As John Terry, who was in charge of the site, clarified almost as if in anticipation of criticism,

> …obviously, a scheme which is to serve as a model for the local people cannot be expressed by the use of building techniques outside the financial or technical reach of these people.[47]

In the post-independence economy of scarcity, the reinforced strive for low-cost methods continued to manifest hybrid structures. For instance, even as the government housing plans by the Madras Improvement Trust in 1948 worked with prefabricated concrete, methods of construction involving elements like bamboo reinforcements and gunite lime were proposed for housing construction in Delhi.[48] As we know in hindsight, ultimately, the quest to build planned concrete villages was not come to fruition in the ways imagined by industrial and architectural experts. Such hybridities continue to persist to this day.

[46] John Terry, "Demonstration Farm Centre", *Marg: A Magazine of Architecture and Art,* Vol 1, No. 3 (1947): p. 33.
[47] *Ibid.*
[48] Karim, *Of Greater Dignity than Riches, op. cit.,* pp. 51-55.

Concrete Roads for Post-War India: an Unfulfilled Crusade

Closely associated with the idea of post-war reconstruction and village uplift was the campaign for concrete roads, which this section delves into. The first concrete road in India was built in Madras in 1914. Unlike, bridges, tanks or urban buildings, concrete did not penetrate the domain of road construction as rapidly.

In 1934, the Indian Roads Congress was set up to promote the development of technical knowledge on the building and maintenance of roads. Mr. Kynnersley, the president of the Indian Road Transport and Development Association (in addition to being a member of the Institution of Engineers and the Editor of the *Indian Concrete Journal* published by the Concrete Association of India), had, since the 1930s, engaged in a relentless campaign for the building of concrete roads. The agents of the government considered him a pioneer, a counterpart of what the Bombay plan represented to the nationalists. Mr. Collins himself revealed this attitude at Virar:

> Some of you must be aware of the so-called Bombay Plan drawn up by ten leading industrialists and public men which gives the ideal of a post-war India, I should not be exaggerating if I say that Mr. Kynnersley and his Association have long ago envisaged this picture. They have for many years been drawing our attention to the importance of roads, they have more recently prepared pilot schemes for roads in four talukas of this Province and now they have given us this concrete example- I use the word concrete in two senses- of what post-war planning should be.[49]

Kynnersley had argued, to begin with, that concrete roads could resist the damage by iron-tired bullock carts as well as fast-moving lorries and buses.[50] He wrote in 1939,

> India being primarily an agricultural country, its development largely depends on the facilities provided for marketing its produce...This necessitates the provision of some means of communication to enable the agriculturist to carry his produce economically to the nearest railway station...as the principal vehicle for the transport of goods in this country is the bullock cart…[51]

[49] "Village Improvement in Virar," *op. cit.,* p. 13.

[50] T. R. S. Kynnersley, "Concrete Roads and the Bullock Cart", *The Journal of the Institution of Engineers (India),* Vol. XIX, Part I (September 1939): p. 138. The Indian Road Transport and Development Association was established in 1927 by the Government of India for research into the road transport sector.

[51] *Ibid.,* p. 155. "If as may be expected, the stone, sand and labour are provided by the villagers the cot should be limited to the price of a small amount of cement. These track-ways will be invaluable for communication between village and village, and between village and road or railway…" See *Indian Concrete Journal* (March 1945): pp. 32, 33.

This argument did not sit well with many Indian engineers at the time. Besides upholding the value of alternative materials like stones or broken bricks, some of them were also concerned about the effects such roads would have on their idealized versions of villages. As Mr. J. Ganguly responded to Kynnersley, "If these roads were constructed with concrete and connected with the main trunk roads, there would be great danger of them being used by motorists, and thus it would disturb normal life in villages."[52]

Under Kynnersley's editorial aegis, the *Indian Concrete Journal* was also highly critical of the government's apathy and lack of vision when it came to transportation infrastructures. "India, as a unit of the British Empire, is an outstanding example of the ill-effects of neglecting communications…", reads an article from May 1945.[53] Clearly, Kynnersley's visions of an extensive network of concrete roads echoed the ideals of the Bombay Plan and the report of the National Planning Committee. "Lenin was building thousands of miles of roads long before all these recent achievements of Russia"[54], he noted, however, before stating that "it is not for a moment suggested that the Government's attitude towards this industry should be one of 'laissez-faire'. There is a middle course between 'laissez-faire' and nationalisation and that is to provide adequate safeguards and to give force and direction to the industry's development."[55]

It is hard to assume that as an important member of both the Concrete Association of India and the *Indian Concrete Journal*, Kynnersley was blind to the vast market which would be opened to the cement industry if his proposals for road construction were accepted.

52 *Ibid.,* p. 162.
53 "Apathy towards transport and lack of vision", *Indian Concrete Journal* (May 1945): p. 57.
54 "Indian Roads and Transport Development Association: Speech of President", *Indian Concrete Journal* (November 1946): p. 259. "Roads are necessary to bring large tracts of inaccessible and untilled lands under the plough to facilitate the distribution of goods and seeds and fertilisers to the farmers to cheapen costs of agriculture and thus induce the farmer to produce a surplus which he can take economically to the market, they are also necessary to prevent perishable produce from running to waste, to link industry with people and develop raw materials and industries", he added.
55 *Ibid.,* p. 260.

Figure 11: Concrete Roads for Villages and Post-war Planning, Advertisements, *Indian Concrete Journal* (February- March 1945)

However, there was another important reason why the emphasis on building a road network had become so pronounced by this time. It is important to place the intensified campaign for concrete roads in the context of the larger debates over other transportation networks in the post-war period. The Second World War had revealed an important bottleneck in the industrial production of cement, related to stalled rail transport and the scarcity of coal.

One of the most important factors in the production and sale of cement is transportation. As a bulk industry with a heavy product whose lifespan is contingent on atmospheric conditions, quick and efficient transportation is key to the delivery of good quality cement. As we have seen earlier, freight (its cost and potential to damage the wares) has always been an issue of concern for manufacturers.

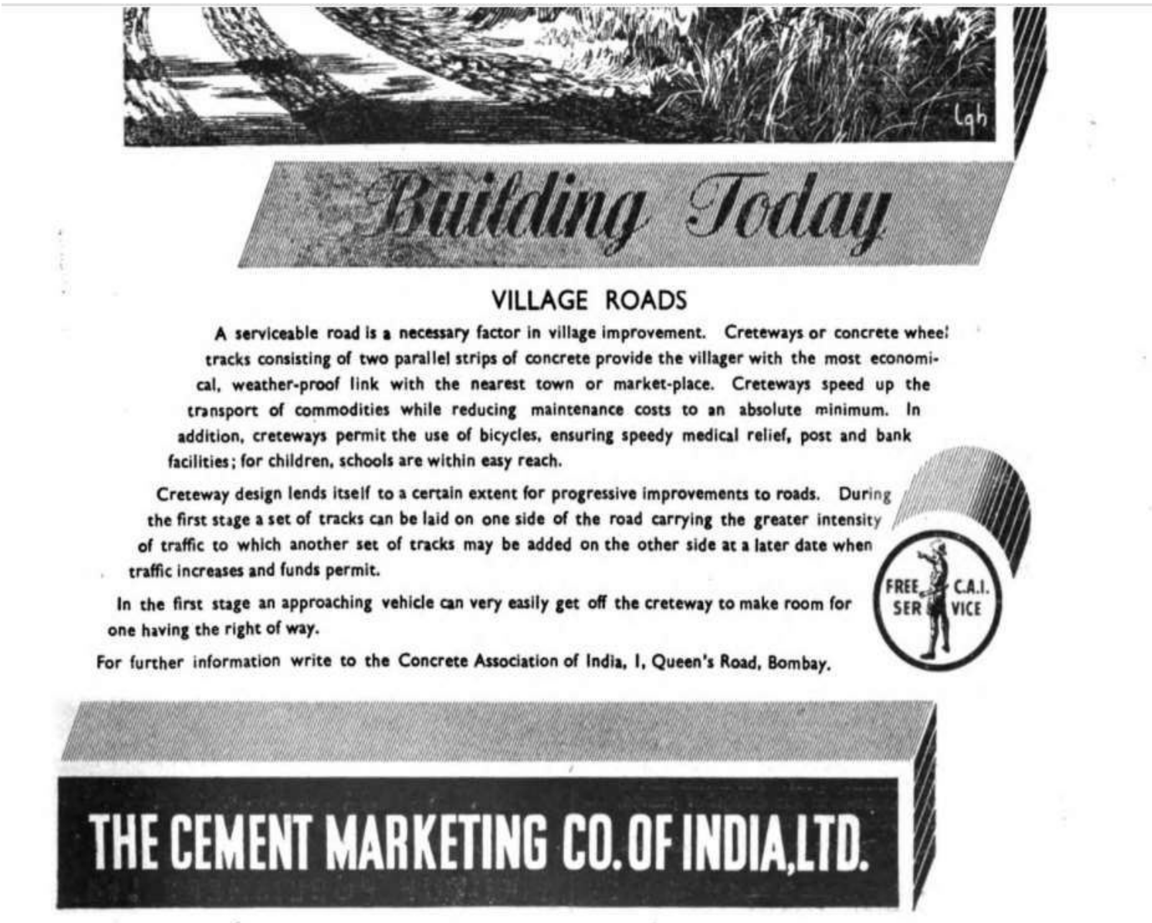


Figure 12: 'Village Roads': Cement Marketing Co., *Marg*, Vol 2, No. 3 (1947).

Networks of transit are so important to cement that Humphrey Ko, writing about cement companies in China, emphasized how

> [t]he nature of cement business is such that those who correctly manage the special logistics and operate in the optimum conditions can expect very high profits in a continuous and simple operation. If continuity can be maintained, this industry can become very profitable in a very short period of time. Getting it wrong would result in extremely expensive discontinuity of operation…Such a situation is therefore, highly likely to cause the speedy collapse of the firm. The success of the cement industry is predicated upon a continuous, smooth growing supply of this "grey gold" by reliable processes and transportation.[56]

[56] Humphrey Ko, *Making of the Modern Chinese State: Cement, Legal Personality and Industry* (Singapore: Springer Verlag, 2018), p. 51.

Figure 13: 'Keep Wagons Moving' and 'Railborne to Victory'. Advertisements in the *Indian Concrete Journal* (1945-1946).

The war years had revealed the limitations of the railway network, and combined with inadequate availability of coal, it presented various difficulties to the industries. An unprecedented amount of goods and personnel had to be transported due to increased military traffic and the burden on the railways increased further due to the closing of shipping lines in the east due to Japanese advances after 1942. This was exacerbated by the shortage of coal which fueled both the railways and the cement industry.[57] Added to this, problems such as pilfering, disappearing wagons and the late delivery of urgent materials troubled the industrialists.[58] It is against this background of the bottleneck caused by the railways that one may read the interest of the cement industry in developing better road transport systems for their imagined future.

Writing on the possibilities of transport after the war, Kynnersley critiqued the "step-motherly treatment meted out to roads", owing, to a great extent, to the "all-powerful" railway interests in both Britain and India. "[W]e must continue to plead the cause of roads which, if allowed reasonably fair play, could do as much or even more than the railways in what we hope may be the peaceful days ahead", he writes, "but the majority of proposals by persons and organisations contain railway apologia".[59] In 1946, the president of the Indian Roads

[57] *Statistics Relating to India's War Effort*, *op. cit.,* p. 33.
[58] "Apathy towards transport and lack of vision," *op. cit.,* p. 260.
[59] "Editorial", *Indian Concrete Journal* (June 1945): p. 73. He continues: "Transport is but one of a vast number of interests which, as at one time transport monopolists, they were able to develop and hold. They are the largest

Congress Mr. L. A Freak, after referencing the Bhore Committee Report and the necessity of developing village communication, argued that "[f]or a long time past, we have felt our road expansion programme being throttled by the influence of railway interests. ...So far we have not always succeeded in getting the Government of India to share this view but we hope that the dawn is breaking on this impasse."[60] A report on the Bombay Chronicle in the aftermath of the war supported such critique, reiterating that the government's road plan designed by the Chief Engineers fell far short of the actual requirements of the country.[61] The report went on to state that the

> public has been accustomed to believe that a countryside is ready to be developed for trade and industry when a railroad is built through it. [But] our trunk railways were designed not so much to help inter-provincial trade as to assist the exporters of India's raw materials. [62]

The sentiment against the railways was clear: not only was it an unreliable method of transportation for the cement industry, it also stood in the way of one of the largest potential markets for the material: roads. The consequent sense of urgency among the proponents of concrete roads is impossible to miss:

> every road user will surely hope that the designers of our post-war roads will not allow their judgment to be influenced by any short-sighted policies and where it is impossible to build roads as they ought to be built, at least let us reserve enough room for the essential needs of the future BEFORE IT IS TOO LATE.[63]

Like the schematizations of rural planning, the campaign for concrete roads did not pan out as expected. Even today, road construction is a field dominated by another material: bitumen.[64] It is interesting to ask why, despite the technically higher strength of concrete – not to mention the campaigns by industrial conglomerates- bitumen continues to be preferred for roads. Apart from the relatively higher cost of concrete paving, perhaps one material reason is that roads are structures which require repeated repair and refinishing over the years, and

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hoteliers, licensed victuallers, and general caterers in the country. They are owners of docks, warehouses, and they practically control the distribution of coal. They are the largest purchasers of steel, building materials, and commodities of every description...The withdrawal of railway orders would bankrupt many a firm, incommode many others, and seriously injure many more. In short, they have a vice-like grip on British industry…The psychological effect of this railway dominance on the public is remarkable..."

[60] "The Indian Roads Congress", *Indian Concrete Journal* (November 1946): p. 251.

[61] *Ibid.,* p. 249.

[62] *Ibid.*

[63] "Editorial", *Indian Concrete Journal* (August 1945): p. 113. [Capitalization original]

[64] Bitumen (or asphalt) is a by-product of petroleum refining, and is made by blending stone and other aggregates with this binding agent to create a distinctively black tarred surface.

bitumen more suited to repair-work than concrete. Asphalt is also more acquiescent to underlying imperfections, whereas concrete requires an even surface for its application. Its skid resistance and imperviousness to temperature fluctuations are also aspects which are often cited as a reason for its choice in road construction over concrete. Further, bitumen work is quicker, and allows for roads to be opened up to traffic faster. Penelope Harvey, in her ethnographic work on road construction in Peru, has argued how "the relational dynamics of concrete reveals how its promise to operate as a generic, homogeneous, and above all predictable material is constantly challenged by the instability and heterogeneity of the terrains to which it is applied."[65] In other words, it could be argued that the particular material demands of the infrastructural category of roads resisted, in a way, their construction in concrete.

...

As Christophe Bonneuil has argued in the context of colonial west Africa, irrespective of the multiplicity of the concerns that motivated the colonial state or the variety of technical solutions implemented, all of its large-scale developmentalist schemes had a crucial common component: they all put experts in power. Over time, the problems of the development came to be reconceptualized as *technical* problems to be resolved with appropriate use of technical expertise. The evolution of expert knowledge was thus predicated on the new forms of standardization and geometrization of developmentalist schemes.[66] Bonneuil's argument can be more broadly applied to contexts beyond the activities of the colonial state, to the cases we have explored.

In early twentieth century India, as this chapter has elaborated, the reinterpretation of developmentalist schemes placed cement and concrete at their nuclei as material technologies that provided solutions to 'technical' problems of hydraulic, social or infrastructural engineering. On the ground practicalities, contingencies of labour and costs, or the properties of other materials often confined their quests to the realm of the ideal. Whereas the post-colonial Indian state did carry forward the hydraulic developmentalist schemes initiated by the colonial government, the quest for concrete villages and roads had to wait. It is only in recent

[65] Penelope Harvey, "Cementing Relations: the Materiality of Roads and Public Spaces in Provincial Peru," *Social Analysis* 54, no. 2 (2010).
[66] Christophe Bonneuil, "Development as Experiment: Science and State Building in Late Colonial and Postcolonial Africa, 1930-1970." *Osiris* 15 (2000), pp. 258-281.

decades that cement has penetrated rural-house building in any significant way. Half a century after the cement industry's imaginations of ideal concrete villages, *pucca* structures are now fast replacing the buildings made with *kuccha* materials. Yet, this transformation is not total, and hybridities persist. Many structures continue to use stone, clay or brick masonry, sometimes mixed with cement mortar, rather than entirely concrete elements. In road construction, as discussed above, infrastructures continue to be dominated by bitumen. Glimpses into the histories of these three infrastructural schemes and the nature of their unfulfilled outcomes, thus, have revealed that the material did not always follow the path industrial or engineering experts had schematized for it in their imaginations of development.

Epilogue

> Bhakra will consume five million cubic yards of concrete before the 760 foot wall is solid enough and bulky enough to staunch the oncoming waters. Some appetite! I thought of this Himalayan hunger for concrete, reading the recent plea by Mr Moraji Desai to save cement. The trickling, fine commodity is in short supply still... [b]ut concrete is the life substance of dams like Bhakra. The royal mixture of cement, sand, stone and water must pour lavishly, if dams are to rise, reservoirs fill, canals flow, and dry lands become fertile again.[1]

This statement, made by a columnist who visited an almost complete Bhakra dam in 1957, best captures the story of cement and concrete in the four decades that followed India's independence. As we have seen, the supply of cement for public demand had always been restricted to a certain extent since the evolution of the cement industry in the inter-war period. Protracting the more structured policy of control initiated during the Second World War, the independent Indian state channelled this material to quench the 'hunger' of the various largescale irrigation and energy engineering schemes laid out by its Five Year Plans.[2] Cement shortages continued to limit the scope of its applications throughout these decades. It was only after the government had initiated decontrol of cement prices in the 1980s, that the material became increasingly available to the larger population as an “off-the-shelf” commodity.[3]

Today, India is the world’s second largest manufacturer of cement, its factories churning out over 337 million tons 2018 and 2019 alone.[4] As the domains of its use expanded over the past few decades, Portland Cement diversified into varieties that are attuned to requirements such as the multiple compression strengths for different scales of structures, resistance to corrosion in marine environments, aesthetic preferences, and environmental conditions like rainfall. Besides the various grades of Ordinary Portland Cement, the current Indian Standard Code for civil engineering specifies varieties such as Portland Pozzolana Cement, Portland Slag Cement, White Portland Cement, Sulphate Resisting Portland Cement, Hydrophobic Portland Cement,

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[1] John Frazer, “Dam's Giant Hunger Eor Cement”, *Times of India,* 10 Feb 1957: p. 8.
[2] See Kumar Bar Das, *Cement Industry of India* (New Delhi: Ashish Publishing House, 1987), pp. 38- 47, for a brief outline of the cement industry in this period.
[3] J. D Bapat, S. S. Sabnis, S. V. Joshi, and C. V. Haazaree. "History of Cement and Concrete in India: A Paradigm Shift." Proceedings of American Concrete Institute (ACI) Technical Session on History of Concrete, Atlanta, USA. 2007.The deregularization of prices was completed in1989.
[4] *Indian Minerals Yearbook 2019: Part III Mineral Reviews, Cement,* 58th Edition, Nagpur: Ministry of Mines, Government of India: July 2020, pp. 2, 9,12.

Low Heat Portland Cement, and Rapid Hardening Cement, among others. 'Cement' remains as plural as ever.

This thesis has been an attempt to look beyond the grey surface of Portland Cement to historicize its materiality in relation to its technological and infrastructural pasts. Such an endeavour primarily entailed acknowledging the pluralities and enduring hybridities that have marked the lives of cement. This allowed us, firstly, to approach Portland Cement as *one* kind of cement that historically came to dominate other kinds of cementitious materials, and examine its industrialization and production against a longer history of experimentation and construction with multiple kinds of cements across the globe. Secondly, it revealed how the popularity of industrially produced 'modern' Portland Cement was closely tied to industrial and engineering rhetoric that disparaged other cements. Finally, it directed us to the instances where the early uses of the material in infrastructure did not bend to the absolute wills of engineers or industrialists but rather necessitated other cements, alternate materials or even hybrid structures.

These themes, in turn, revealed to us a history of how the material technology of cement and concrete became embedded in the practice and writings of military and imperial engineers in the nineteenth century, how a standardized singular cement later came into the limelight and proliferated through industrial channels, and how this 'modern' form came to be inextricably tied to infrastructural imaginations of the twentieth century. Through these explorations, this thesis attempted to underline how the material identities of cement shaped and were in turn shaped in particular by the agencies of engineers, industrialists and other experts.

However, what has been kept outside the ambit of this thesis owing to the limitations of archives and time, firstly, is a more elaborate discussion on labour. The material and technological transformations of cement had tremendous implications not only for the evolution of expertise in the construction industry, but also the corresponding hierarchization of labour practices. The systematic differentiation of construction labour into 'skilled' and 'unskilled' work- often in gendered ways- and the transfiguration of the embodied work of mixing, carrying, and constructing with cement, are important historical transformations that warrant more meticulous and exhaustive discussions.[5]

The second important theme that this thesis has only tangentially addressed, is the establishment of an extractive regime, over the course of the twentieth century, that sustained – and continue to underpin- cement production and the construction industry. Producing cement is a highly energy intensive process with major implications for the location of the industry, carbon emissions and fuel policy. Exploring the histories of spatiality, geopolitically expansive extractive networks and the environmental implications techno-industrial complexes can also compel us to consider cement in connection to a history of energy and its consumption.

Indeed, this thesis set out with the objective of historicizing a material whose future is presently under animated debate: concerns regarding the environmental consequences of their production and use dominate discussions around concrete and cement. Concrete is the second-most widely used material on Earth after water, and has been referred to as nothing less than "the most destructive material" on the planet.[6] Throughout the stages of its production, concrete contributes to approximately 4-8% of the world's carbon dioxide. The air pollution caused by limestone quarries and cement factories, its heat and gas trapping effect in cities, its tremendous industrial water use, and its destruction of hydraulic ecosystems through extractive ancillary industries like sand mining, are indications of its cataclysmic existence.[7] It is not surprising then, that the latest addition to the varieties of cement, though far from popular still, is Green Cement or Green Crete, an allegedly zero-carbon eco-friendly cement based not on limestone but on sludge and recycled waste materials.[8]

Cement and concrete continue to evolve, not only within the channels and conventions of testing, research and development established by technological and industrial systems in the

[5] Consider, for instance, the gendered division of skilled and unskilled construction work, particularly from the 1970s. See Rahul, "Participation of the Female Workers in the Construction industry in India: A Review", *Social Science Research Network* (October 2014) for an analysis of the categories of work in relation to female labour.
[6] Jonathan Watts, "Concrete: the most destructive material on Earth," *The Guardian,* 25 February 2019.
[7] *Ibid.* See Barbara-Harris White and Lucia Michelutti ed. *The Wild East: Criminal Political Economies in South Asia* (London: UCL Press, 2019), for analyses of sand mining and the criminal assemblages that have developed around it. Also see Eli Elinoff, "Concrete and Corruption: Materializing power and politics in the Thai capital," *City* 21*,* no. 5 (2017): pp. 587-596 for in interesting discussion on the relationship between Thai citizens and their reading of the social relationships of corruption as materialized in concrete infrastructures.
[8] "Green Cement - A Revolutionary Product And Also Need Of The Hour Of This Decade," *Outlook,* 1 April 2021.

twentieth century, but also through its use as an everyday technology. Cement is also a domestic material with many minor and invisible lives, often shaped and used by non-professional labour. Patched walls, repaired leaks, uneven lumps holding metal posts in place, and other minor appendages constructed in cement form our built environment as much as large bridges or multi-purpose dams. Investigations into the ways did this material technology arbitrates our everyday life in unexpected ways, can reveal new dimensions of its materiality.

The untold stories and trajectories of cement in South Asia are, thus, numerous. This thesis has been a small step toward opening up this relatively underexplored material to new methods of historical investigation. In doing so, it hopefully heralds many rich illuminating studies on this omnipresent material in the future.

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