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Research Article

The Concrete Paradox: Growth, Sustainability, and the Structural Transformation of India's Cement Industry

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Abstract

One of the key industries driving infrastructural development, urbanisation, and economic growth in India is the cement industry. India is the world's second-largest producer of cement, and its cement industry has experienced substantial structural change. Regulatory compliance, environmental sustainability, and energy consumption are some issues that the industry must deal with. This research paper examines the industry's growth path, market structure, capex plans and sustainability efforts. Using secondary data from industry publications, government reports, and academic studies, the research examines production & consumption trends, demand drivers, and key risks (understanding the whole industry at bottom level).

The findings reveal that commercials, housing development and government initiatives like smart cities and highway projects continue to boost the demand for cement, while keeping competitive performance and the key historical financials trends. The industry is also increasingly utilizing green power, alternative fuels & alternative raw material and waste heat recovery systems (WHRS) to lower carbon emissions. The paper concludes that, although the industry is still being a fundamental pillar of India's economic growth, long-term competitiveness will rely upon the technological innovation, sustainability integration and regulatory alignment.

Background and Purpose: Construction industry stands as one of the country's biggest contributors to the economic growth of India, accounting for 09% of the country's GDP, besides being the second largest employer of labor after agriculture, with 71 million people employed in the construction industry in 2025-26, which is projected to grow to over 100 million by 2030. Cement is the main material used in the construction industry. The purpose of this study is to analyze Indian Cement Industry with its growth, value chain, drivers, challenges and sustainability.²

Methodology: The study employs a descriptive research approach and draws on secondary data sources, including academic literature, industry publications, government reports, and corporate annual reports. Qualitative and trend analysis techniques are used.

Key Findings:

- Cement industry is under the consolidation phase.
- Delaying in the central & state capex creating hurdle in the recovery of demand.
- Geopolitical tension denting on the margins.
- Capturing the market share thorough M&A rapidly increasing in this space.

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- Sustainability concerns are pushing companies toward green technologies.

Conclusions: The demand for cement in the Indian market is expected to grow steadily with the strong demand of infrastructure and rapid growth of rural economy and urbanization. However, environmental sustainability and energy efficiency will have a significant influence on the sector's future competitiveness.

KEYWORDS: Indian Cement Industry, Infrastructure Development, Housing, Sustainability, Construction Sector, Economic Growth.

1. INTRODUCTION

1.1 Background and Context

The cement industry is one of the most important core industries of infrastructure development and economic growth. Cement is an essential part of building bridges, houses, roads, dams and other infrastructure structures. The cement industry of India consists of 160 large integrated cement factories, 130 grinding units, and 62 minor cement factories. About 453 million tonnes of cement were produced in FY25, while the installed capacity of India's cement industry currently stands at approximately 690 MTY.

Most of the cement industries are located near raw material sources in India. Over 85% of the cement industry is in the states of Rajasthan, Andhra Pradesh, Telangana, Karnataka, Madhya Pradesh, Gujarat, Tamil Nadu, Maharashtra, Uttar Pradesh, Chhattisgarh, and West Bengal. The installed capacity of the industry is adequate to meet the domestic cement demand. In India, the per capita demand of domestic cement is approximately 300 kg, whereas in the world it is 520 kg.

The cement industry is mainly driven by urbanisation and robust infrastructure development. The government's focus on large-scale projects like "highways, trains, smart cities, housing schemes, rural development, and industrial growth" will drive cement demand to surge.

The development of the infrastructure and construction sectors has been linked strongly with the development of the Indian cement industry. In recent years, the demand for cement has been very high due to the various initiatives taken by the government, like Housing for All, Smart Cities Mission, Bharatmala project, and infrastructure modernisation project.

Moreover, the industry has also experienced structural change in terms of large corporate groups entering into the market, business consolidation through mergers and acquisitions, and the use of innovative manufacturing technologies.³

1.2 Research Problem and Questions

This research addresses the following questions:

1. What are the major growth drivers of the Indian cement industry?
2. What Challenges the industry is facing in current environment.
3. What technological innovations can improve the industry's long-term sustainability?

1.3 Research Significance and Novelty (compare from existing research)

2. RESEARCH METHODOLOGY

2.1 Research Design and Approach

The study examines the performance and structure of the Indian cement industry using a descriptive research approach. The method is a combination of qualitative analysis and a trend analysis of industry data.

2.2 Data Sources and Collection

The research is based on **secondary data sources**, including:

- Government publications
- Reports from industry bodies such as the (Cement Manufacturers Association)
- Company annual reports
- Market research reports and policy documents

2.3 Analysis Framework

The analysis framework includes:

- Industry structure analysis
- Demand and supply dynamics
- Policy and regulatory environment
- Sustainability initiatives and environmental impact
- Comparative analysis with India cement markets

2.4 Limitations

The study has been conducted based on the secondary data, which includes some limitations on data accuracy and timeliness. In addition, the emphasis of the research is placed primarily on the macro-level characteristics of the industry instead of the firm-level financial performance.

3.1 Indian Cement Industry Performance

India is the second-largest producer of cement in the world after China. The average consumption is about 300 kg per capita, which is 3 times less than the per capita consumption in China (1,350 kg per capita). With an assured demand from the housing and infrastructure sectors, the cement sector has tremendous scope for growth and improvement. On the demand side, the market for cement experienced moderate growth at 4-5% for FY2024-25, following a healthy compound annual growth rate (CAGR) of 11% during FY2022-24. The main reasons for this relatively healthy increase were: to a large extent, the high base effect from last fiscal year, the lull in construction activity in the first half of this fiscal year due to a prolonged hot spell, and a shortage of labour during the election. Increasing input costs, particularly fuel and raw material prices, offset some of the gains made in efficiency for a few companies.

Demand for cement in India is expected to grow strongly, reaching more than 630 MMT by FY29 from 467 MMT in FY25. The growth, which is around 6.0% CAGR, is predominantly attributed to the growth in the infrastructure development and construction activities throughout the country. Cement demand is anticipated to be driven in the near future by strong economic fundamentals, such as strong GDP growth, India's transformation to a middle-income nation, and an increasing working-age population. However, the sector is also contending with challenges, such as in FY25 cement prices declined by 5 per cent YoY.

In Q4FY26, industry players will raise prices in across regions

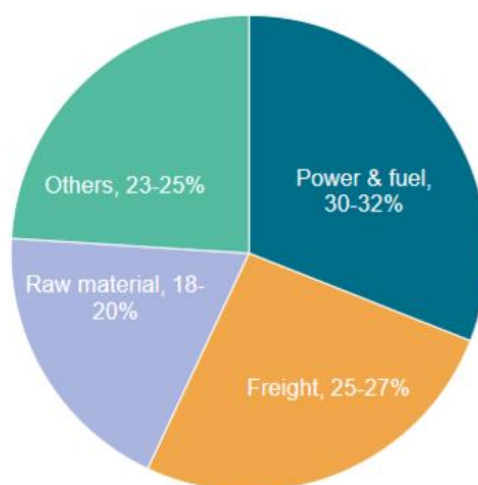
due to improving demand. The early signs of price revival seen in South India, the management's priority in FY27 is moving from volume to value, which may help sustain price increases. Cement volumes are predicted to expand by about 7-8% in FY26 due to a sustained, strong demand for urban housing, an expected rise in government investment on infrastructure projects, and a likely increase in rural consumption supported by improving agricultural cash flows.

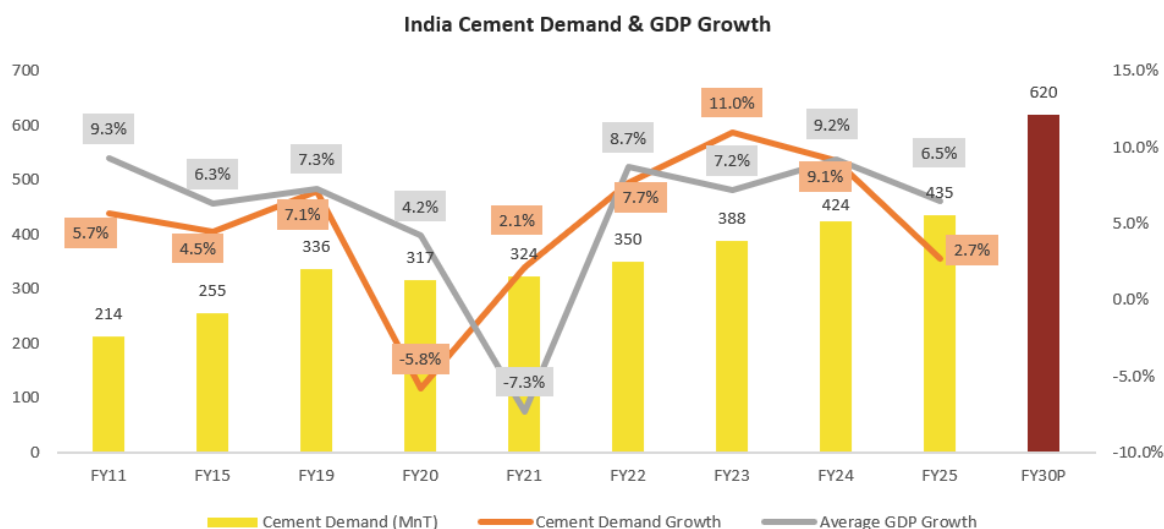
Delay in central and state capex will have a negative effect, but will offset by rural recovery. The cement industry may finally experience the long-awaited combination of a volume growth and profitability with price discipline returning and rural

Pan-India trend in cement prices



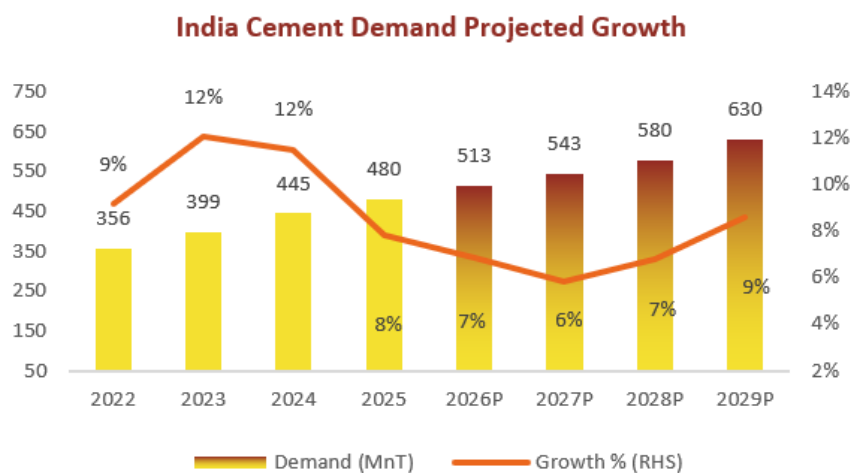
Major Cost Associated with Cement Production





Source: Ultratech Cement Dossier

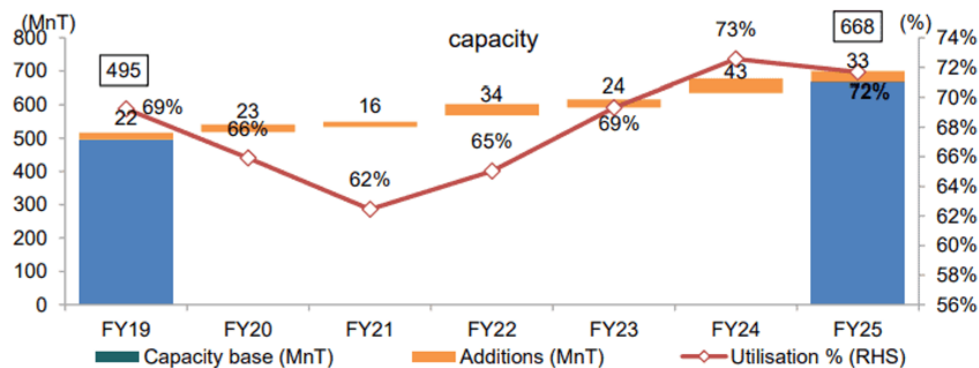
Note: Cement Demand include only Grey Cement



Source: Imarc

Pan-India supply review

Figure 13- Historical capacity additions and capacity utilisation trend

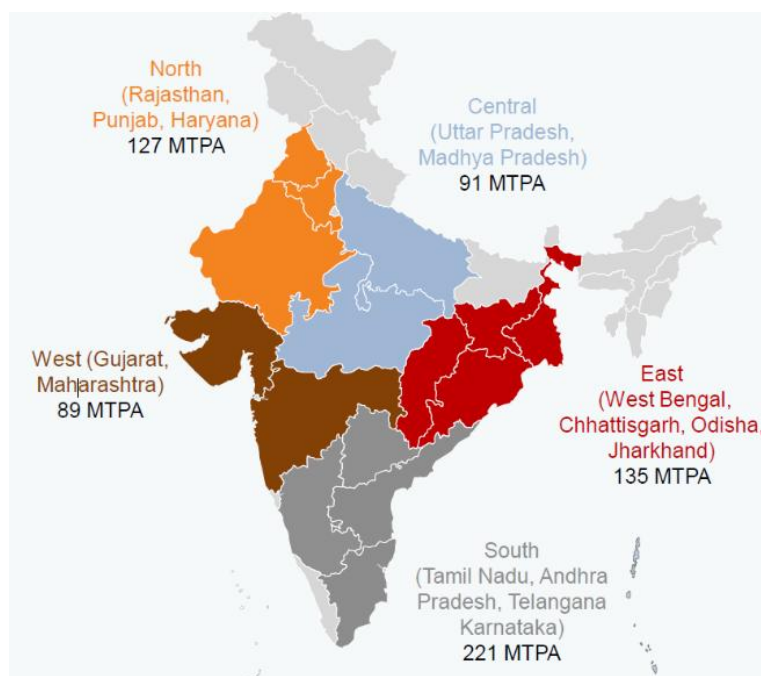


Region-Wise Demand Growth

Particulars	FY22	FY23	FY24	FY25	FY26	FY25-FY29P
PAN-India	8%	12%	11%	5%	6.5-7.5%	7.5-8.5%
North	12%	9%	12%	6.50%	4-5%	6.5-7.5%
South	14%	13%	12.5%	2%	6.5-7.5%	7-8%
East	1%	14%	9%	5%	6.5-7.5%	8.5-9.5%
West	9%	10%	13%	8%	6-7%	6-7%
Central	8%	12%	12%	4%	7.5-8.5%	7.5-8.5%

Source: JSW RHP

Installed capacity & key markets in each of the Geographic Regions



Player-wise capacity growth (top 10 players)

MTPA	Fiscal 2015	Fiscal 2020	Fiscal 2022	Fiscal 2023	Fiscal 2024	Fiscal 2025	Fiscal 2015-2025 CAGR	Fiscal 2020-2025 CAGR	Fiscal 2023-2025 CAGR
UltraTech Cement	60.2	111.4	114.6	126.9	140.8	183.4	11.78%	10.49%	20.22%
Ambuja Cement	59.7	62.7	67.5	67.5	78.9	100.2	5.31%	9.83%	21.84%
Shree Cement	23.6	40.4	46.4	46.4	53.4	56.4	9.10%	6.90%	10.25%
Dalmia Bharat	24.0	26.5	35.9	38.6	44.6	49.5	7.51%	13.31%	13.24%
Nuvoco Vistas	13.3	22.1	23.6	23.6	25.0	25.0	6.51%	2.50%	2.92%
The Ramco Cement	16.5	18.8	19.4	22.0	22.8	22.8	3.29%	3.94%	1.80%
JK Cement (India - grey cement)	10.5	14.0	14.7	20.7	22.3	24.3	8.75%	11.66%	8.35%
JSW Cement	6.1	13.4	14.6	16.3	20.6	20.6	12.96%	9.00%	12.42%
Birla Corporation	9.8	15.4	20.0	20.0	20.0	20.0	7.39%	5.37%	0.00%
JK Lakshmi	8.3	13.3	14.0	14.0	16.5	16.5	7.11%	4.41%	8.56%
Industry	419.0	518.0	568.0	592.0	635.0	668.0	4.77%	5.22%	6.23%

Source: JSW RHP

Player-wise sales volume (Top 10 players)

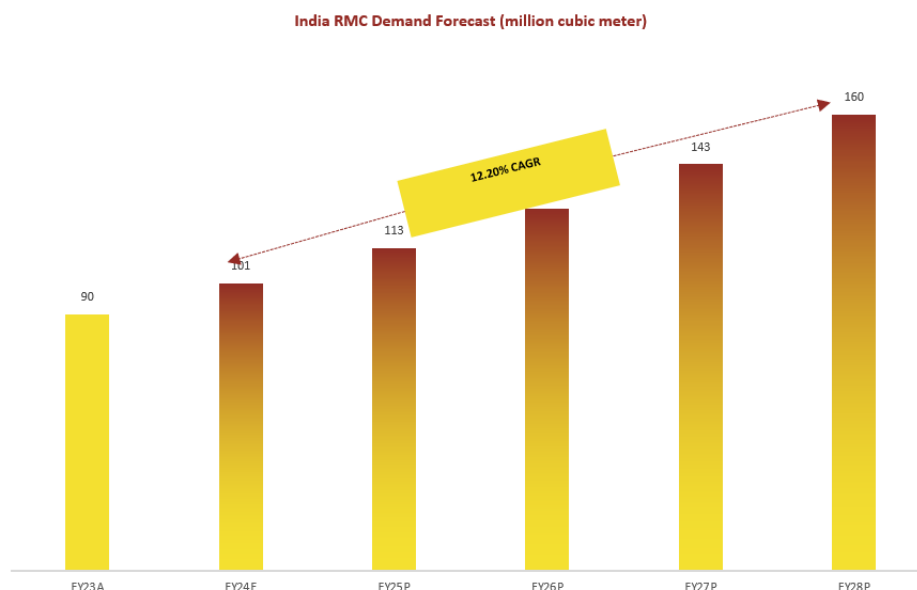
MTPA	FY15	FY20	FY22	FY23	FY24	FY25	FY15-25 CAGR	FY20-25 CAGR	FY23-25 CAGR
UltraTech Cement (India - grey cement)	44.9	77.5	87.3	100.1	112.8	125.1	10.8%	10.1%	11.8%
Ambuja Cement	45.8	47	53	68	58	63	3.2%	6.0%	-3.7%
Shree Cement	16.2	24.9	27.7	31.8	35.5	35.9	8.3%	7.6%	6.3%
Dalmia Bharat	10.8	19.3	22.2	25.7	28.8	29.4	10.5%	8.8%	7.0%
Nuvoco Vistas	9.4	10.7	17.7	18.8	18.8	19.4	7.5%	12.6%	1.6%
The Ramco Cement	7.7	11.2	11	14.9	18.4	18.4	9.1%	10.4%	11.1%
JK Cement (India- Grey & White Cement)	6.8	9.57	14	16.2	19.1	20.2	11.5%	16.1%	11.7%
JSW Cement	2.7	7.4	9.7	10.5	12.5	12.6	16.7%	11.2%	9.5%
Birla Corporation	7.6	13.8	14.2	15.8	17.8	18.1	9.1%	5.6%	7.0%
JK Lakshmi Cement	5.9	10	11	11.4	12	12.2	7.5%	4.1%	3.4%
Industry	257.1	326.5	355.8	399.4	445	466.9	6.1%	7.4%	8.1%

Source: Company & peer company analysis, Crisil Intelligence

3.2 Indian Ready Mixed Concrete (RMC) Market

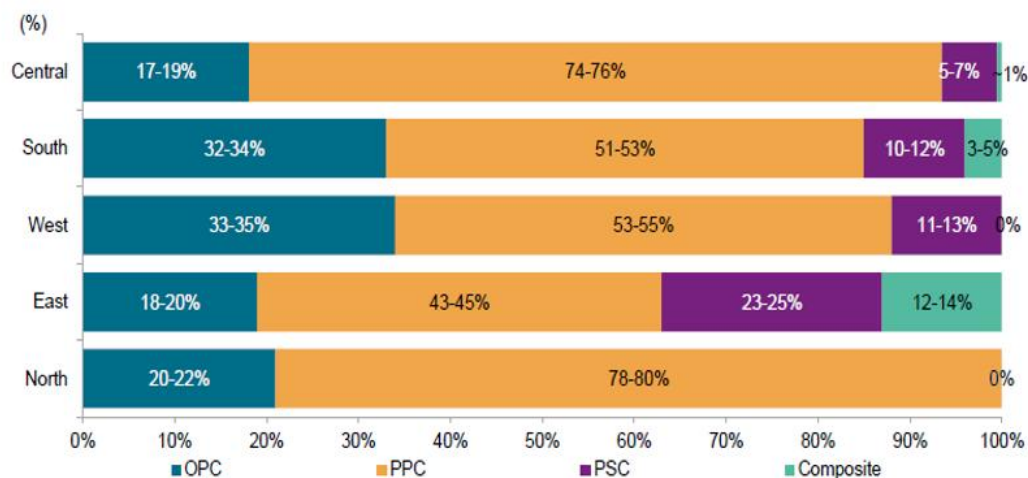
By FY33, the India RMC market is anticipated to expand from \$81 billion in FY24 to \$167 billion, with a compound annual growth rate of 8.45% from 2025 to 2033. A variety of factors, such as infrastructure projects, urbanization, real estate growth, government initiatives, highway expansion, smart city developments, cost efficiency, rising construction, labor shortages, sustainability focus, quality consistency, advanced batching technologies, foreign investments, time-saving benefits, and a growing demand for durable building materials, are contributing to the expansion of India's ready-mix concrete market. With the construction industry's growing adoption of low-carbon technologies and eco-friendly materials, sustainability is changing the RMC market in India. The use of recycled aggregates, fly ash and slag in green concrete is becoming more popular because of environmental regulations and company sustainability policies.

In FY23, 90–92 million cubic meters of RMC were demanded domestically. By FY28, it is predicted to rise by 10–12% CAGR to 155–160 million cubic meters. The demand for RMC from sectors like IT, BFSI, hospitality, tourism, education, capital goods, etc. is anticipated to gain additional momentum from good investments in commercial real estate. The consumption of RMC will be sustained by the continuing adoption of RMC and industrial construction, which encompasses power plants, small and medium-scale enterprises, ports, sewage treatment plants, and airports. The India RMC market is moderately fragmented by leading players in the industry are – UltraTech, Ambuja, ACC, Dalmia & Shree cement have leverage of captive plants, bulk cement terminals & large truck fleets. The growth drivers & risk of RMC market are similar to grey cement demand.



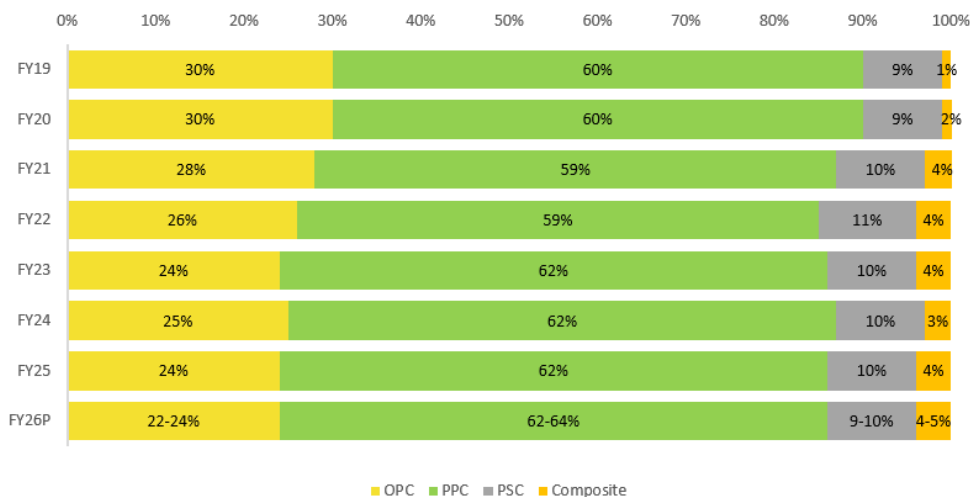
Source: IMARC, JSW RHP, Mordor Intelligence

Region-wise Product Demand Split



Source: Crisil intelligence, Industry

Product Wise Demand Outlook



Source: JSW DRHP

4. Cement Industry Value Chain

The cement industry starts with the raw material procurement from the quarries and ends with the customers (Housing, Infrastructure and industrial) getting the end use of product. In the production of clinker, limestone is a crucial input. Cement is manufactured with additives including gypsum, iron ore, and bauxite. Quality of cement is dependent upon the proportion of additives and the grades of limestone used. Similarly, the selection of fuel is dependent upon the efficacy of the process, the cost, and the availability of the fuel. To address the scarcity

of these inputs and their escalating costs, players are looking at substitutes manufactured from "waste oils, agricultural waste, rice husk, animal feed, etc". Looking on the each stage of value chain each process include the value drivers that will create economic moat for the company. The following stages of value chain are explained below.

1. **Extraction of Raw Materials and Crushing:** Limestone is the primary raw material extracted from the quarries by blasting & crushing. Other raw materials like clay, gypsum, silica, iron ore, and by-products such as fly ash and slag are

also sourced. The value drivers in this stage when company secured raw material linkages like long term tie up with suppliers which will help in consistent availability of critical raw material with that maintain consistent quality & efficient mining operations. Then the extracted limestone crushed into smaller sizes and stored in stockpiles and homogenized to ensure uniform quality.

2. Raw Material Preparation & Grinding:

Before being burned in the kiln, raw materials—which include limestone, clay, and additives—are metered and ground into a fine powder known as raw material. After that, the raw meal is combined and ready for kiln processing. There are two kinds of mills: ball roller mills are used for smaller plants, while vertical roller mills are used for big capacity. The kind of raw material, the amount of electricity used, and the project budget all affect the mill choice. Separators/classifiers are employed in contemporary mills to separate the fine product and return the coarser particulates to the grinder.

3. Clinker Production (Calcination):

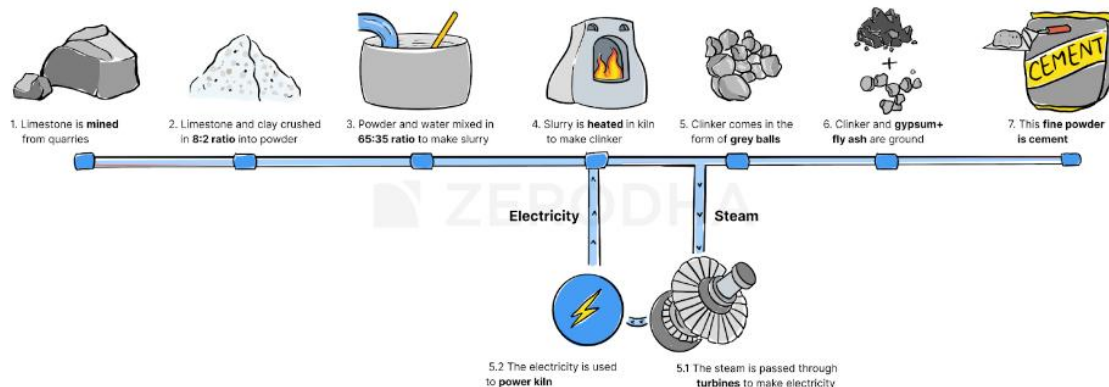
The first silo is subsequently utilised to store raw feed, while the second silo is continually blended and the large silo is stored concurrently. The raw meal is mixed and then heated to about 1450°C in a rotating kiln to create cement clinker. After that, the clinker goes through a cooler before being further ground. The heat is recovered and used again as secondary combustion air in the kiln. Thermal efficiency, the usage of alternative fuels, and WHRS are the value drivers at this point.

4. Cement Grinding

Clinker that has been cooled is ground with gypsum in a separate grinding mill to produce cement. Depending on the type and quality of cement being made, limestone, fly ash, blast-furnace slag, natural pozzolanas, etc., may be added to the clinker. The "clinker, gypsum, fly ash, and slag" combination is next processed using "a ball mill, vertical roller mill, or roller press" into a fine, uniform powder. Silos are used to hold the cement before it is transported in bulk or in bags. Clinker is ground with additives like gypsum to control setting time. The result is the fine powder known as cement. The value drivers in this stage are grinding efficiency, product diversification & brand quality & consistency.

5. Packaging and Distribution

Cement is packed in bags or bulk. Distribution takes place via trucks, rail, or ships to wholesalers, retailers, and end-users. Logistics is account for 30% in total cost of cement productions its being affected by diesel prices & cement plant network. Here, the cost of freight will be optimized by the reducing the lead distance by improving the regional reach, dealer relationship & improving the supply chain. Branding, product availability & technical support build brand trust which improve the end user demand (housing, infrastructure & commercial). Each stage involves stakeholders such as mining companies, cement manufacturers, logistics providers, and end-users in construction and infrastructure.



Source: Zerodha

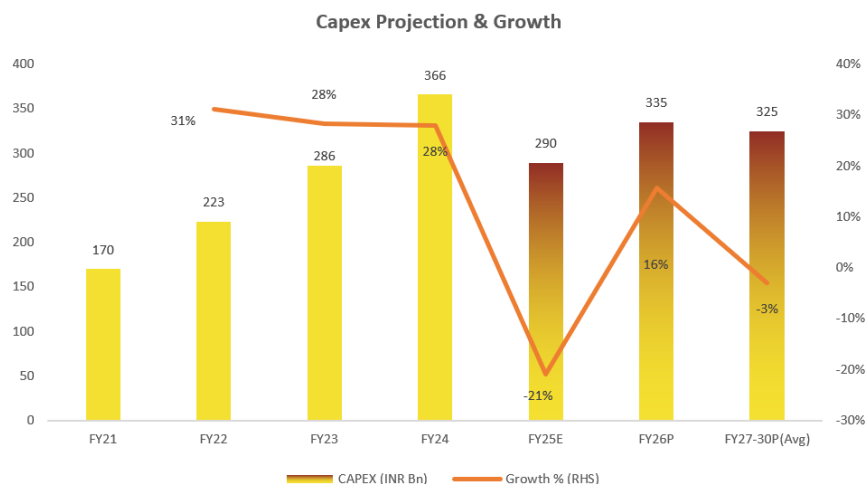
5. Capacity addition by Industry Players:

The Indian cement industry is expected to have spent between INR 1300 and 1350 billion on debottlenecking, brownfield expansions, and maintenance of existing plants over the last five years (FY21-25E). As demand has rebounded in the past three fiscal years and competitive intensity has increased, participants, particularly those of a significant scale, are implementing substantial capex over the next five years in order

to capture market share. The balance sheets of both large and a few mid-sized firms with a significant market presence have been fortified by robust demand, which has incentivised them to increase their capacity by leveraging their strong cash accrual and credit profiles. The installed capacity was around 668 MTPA in fiscal 2025. Assuming that over the next five years (FY26–30), cement companies are likely to increase 220–250 MTPA grinding capacities, reaching 850 MTPA with an

investment amount that is roughly 1.2 times the capital expenditure of the preceding five years. Between FY26 and FY30, industry is predicted to invest INR 1600–1700 billion. The major players would bear the majority of this capital expenditure. Internal accruals are expected to finance a large

percentage of this capital expenditure because of their strong balance sheets and high liquidity. However, due to the high base in last 3 years the growth of capex is coming down this may early sign of saturation in the sector.



Source: JSW RHP

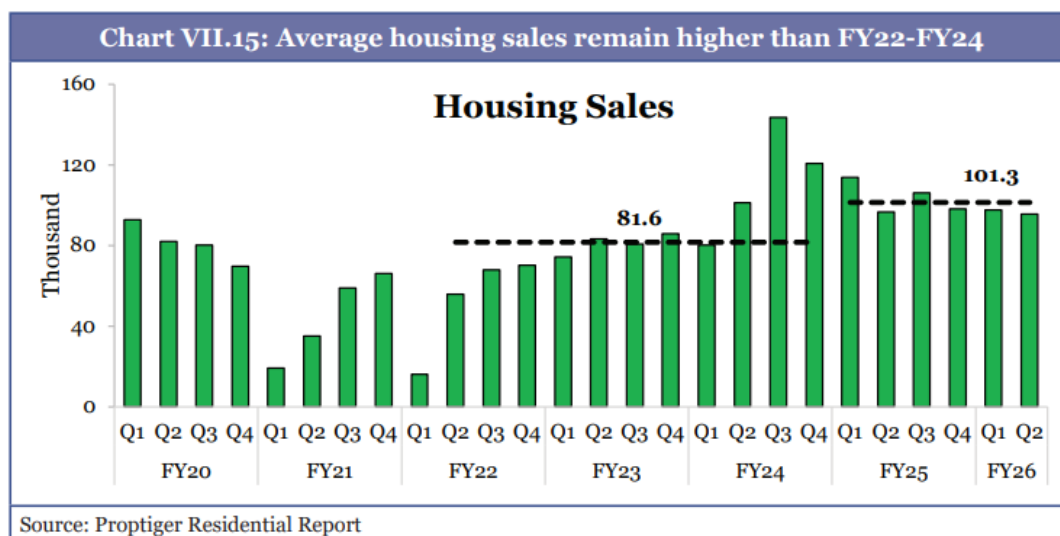
6. Key Growth Drivers Indian Cement Industry

Urban Housing:

Urban housing demand mix constitute 31% ~ 135 MnT in FY25 expected to grow at CAGR of ~7% reaching the 188 MnT by FY30. The share of urban population is rising consistently from over the years. It is 35% in 2020 and is predicted to rise to 40–42% by 2030, when the number of people living in cities will double to 951 million. Increased both commercial and residential infrastructure is required as a result of this change. One of India's most significant growth drivers is urbanization,

which will provide jobs, increase per capita income, and channel money into the construction of new industrial homes. The average household size decreased from 5.3 in 2011 to 4.6 in 2019, which means that more housing units will be needed, contributing to the trend of increasing nuclearization in Indian families during the past several years. India would require more than 144 million new homes by 2070 to meet the country's rising demand, since nuclear families make up more than half of all households.

Rural Housing:



India's rural sector contributing ~ 50% in total GDP. Rural housing accounting 38% of cement demand in India ~164 MnT in FY25 expected to reach ~225MnT by FY30. In 2025 Union Budget government prioritized the rural development under the SDG goal safe & affordable housing by various schemes like Pradhan Mantri Awas Yojna - Grameen (PMAY – G) budget estimate of INR 54,917 crores higher than the previous year INR 32,500 crores. Increasing rural farm income, favourable monsoon and expansionary policy of central bank & government supporting the rural growth. Due to a lower development base and an ongoing increase in the concretisation of kuccha homes, rural housing will surpass urban housing in the housing segment's robust growth trajectory.

Infrastructure:

The India's infrastructure sector is expected to witness robust growth in 2025 & upcoming years. The growth will be supported by the rising government capex, participation of private players, decreasing interest rates & inflation rate. In the Union Budget 2026–2027, the government allocated INR 12.2 lakh crores (12% more than FY25) for industrial, housing, and road infrastructure projects, which will greatly increase the need

for cement. Cement consumption would increase as a result of “government initiatives such as the PM Gati Shakti-National Master Plan, National Infrastructure Pipeline (NIP), Smart Cities Mission, and AMRUT”, which aim to improve port capacity, digital infrastructure, and multimodal transportation. Due to the growth of metro networks, improvements to road networks, and improved connectivity, demand is growing not only in tier 1 and tier 2 cities but throughout the country. According to the 2026–2027 budget, the Ministry of Road Transport and Highways will receive INR 3,09,875 crores, while the railway will receive INR 2,93,030 crores, with YoY growth of 8% and 10%, respectively. “Mumbai-Pune, Pune-Hyderabad, Hyderabad-Bengaluru, Hyderabad-Chennai, Chennai-Bengaluru, Delhi-Varanasi, and Varanasi-Siliguri” are the seven high-speed rail lines that have been announced spanning major growth areas. Announcement of big AI & Data centre projects in south region will boost the industrial growth & infrastructure demand which is largest capacity holder in India. In Karnataka investment of INR 17,183 crores approved across different sectors expected to generate 12,500 new jobs. Given below table showing the allocation of capex to the sectors expose to the cement industry.

Figures in (INR Crores)	FY25RE	FY26BE	Increase/Decrease (%)
Total Capex	1095755	1221821	12%
Roads	287142	309875	8%
Railways	265200	293030	10%
Metro & MRTS	27450	28740	5%
AMRUT and Smart Cities mission	7500	8000	7%
PMAY Urban	7800	21625	177%
PMAY Grameen	32500	54917	69%

Source: Economic Survey 2025-26

Source: JSW RHP, Budget 2026-27

Housing and Real Estate:

India's housing market is expanding in both urban and rural areas due to rising homeownership aspirations and government support for rural housing. Especially after the post-pandemic period India's real estate sector grown at ~ 3.5x. In 2021 the Indian real estate market size is \$200 billion is forecasted to reach \$650 billion by 2025 & \$1 trillion by 2030 around growing at CAGR of 20% (2022-30). The market for affordable housing is estimated to be around INR 67 trillion. It contributes 65% in total cement demand playing the major role in driving the India's cement industry growth story. The demand for housing might reach 93 million units by 2036 due to urban expansion and the next wave of growth in smaller cities, while the home loan market is expected to expand at a rate of 15% annually over the following ten years. Retail real estate, representing 20–25% of the market, is benefiting from renewed consumer spending, organized retail expansion, and the development of new malls and high-street outlets across urban and semi-urban areas.

Industrial & Commercial:

Industrial & commercial market growth is rapidly driven by the increasing urbanization and adoption of new technologies. Record activity in metros such as Bengaluru, Mumbai, Delhi-NCR and Hyderabad has kept office spaces as the biggest share of the commercial market, occupying 40-45%. Flexible workspaces and co-working arrangements are becoming a growing trend in the sector as hybrid working and technology-led office solutions are becoming commonplace.

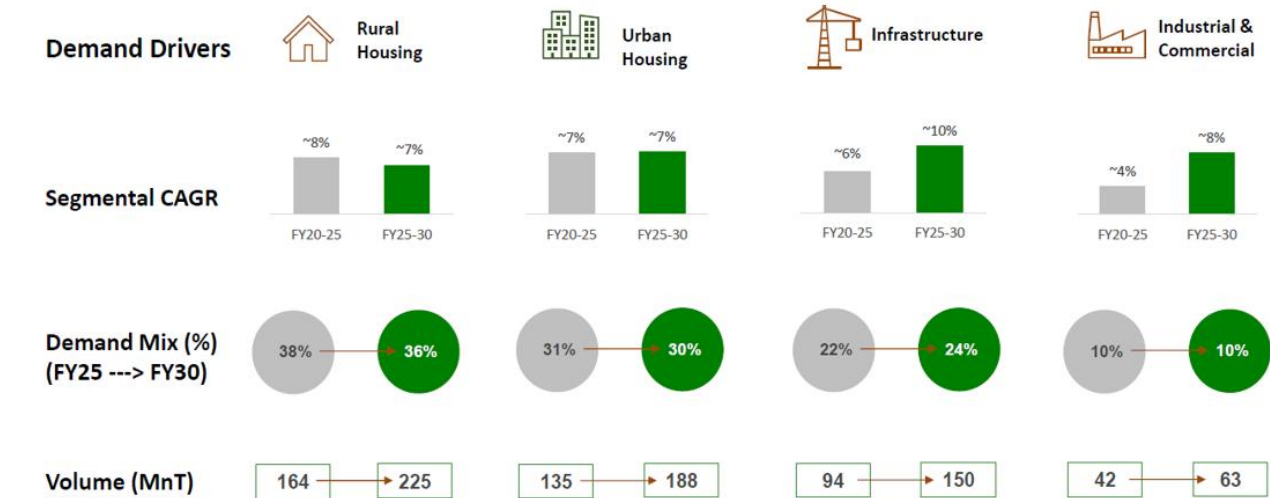
Industrial and warehousing spaces account for 15-20% of the market and are expanding quickly due to the rise in e-commerce, the demand for 3PLs, and government programs like "the National Logistics Policy and the establishment of freight corridors.

Sustainability Initiatives:

Environmental consciousness, and laws and regulations that are becoming increasingly demanding, are becoming strong growth drivers for the cement industry and are paving the way for change rather than hindering it. Companies are being compelled to invest in cleaner and more energy-efficient technologies and

to implement the circular economy as a result of these forces, which are propelling innovation. Due to sustainability trends in the construction industry, there is a growing demand for green cement, which is opening up new premium market niches and greater realization potential. Green cement can help to cut up to 40% carbon footprint of buildings. Because of its capacity to offer superior value to both residential and commercial

segments, policy preferences, and the expansion of investment flows for "environmental, social, and governance (ESG) criteria", it has become more appealing. Furthermore, companies that are proactive in meeting or surpassing environmental standards are obtaining a competitive advantage. They are also gaining traction with more ESG-minded investors and are also enjoying policy-driven incentives.



Source: Ultratech Cement Dossier

Industry Annual cost & margin as % of Revenue

	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25	2025-26F
Raw material cost	12.77%	13.62%	13.67%	14.46%	16.72%	19.16%	19-21%
Power & Fuel cost	19.89%	18.23%	23.54%	29.66%	23.69%	22.02%	20-22%
Freight cost	22.42%	22.20%	22.61%	22.23%	21.30%	22.63%	21-23%
Other Cost	23.35%	20.99%	19.79%	19.50%	21.13%	19.81%	18-20%
Margins	21.58%	24.96%	20.39%	14.16%	17.60%	16.38%	18-20%

Source: Crisil intelligence, Industry

➤ Challenges faced by Cement Industry:

1. Volatile Input Cost:

Most of the cement production cost associate with the procurement of limestone, coal & pet-coke. In FY25, raw material costs made up about 18% of the overall cost of sales due to their heavy nature and transportation economics. In addition to limestone, fly ash, slag, and gypsum are important raw materials utilized in the production of cement. Above chart showing that the raw material cost increase from ~13% in FY20 to ~19% in FY25. Due to the Russia-Ukraine War, the xtremely energy-intensive cement industry saw unpredictable changes between FY21 and FY23, with fuel costs accounting for almost 30% of the entire cost of cement sales. Impacted the margins heavily during that period from 25% peak in FY21 to 14% low in FY23.

2. Pricing Pressure and Regional Competition:

Pricing power is limited due to commoditized product create frequent price war in the market. Negatively impact the margins & profitability. Company's actively working on improving the cost efficiency to offset the impact of higher energy price and regional competition.

3. Overcapacity & Supply additions:

Industry capacity expansion is faster than demand growth by large players reducing the capacity utilisation and EBITDA/ton.

4. Environment & Regulatory Pressure:

Cement is carbon intensive generate ~7% of global CO2 emissions. Increasing government regulation carbon taxes, ESG compliance and WHRS mandates increasing capex in green tech. Environmental issues are handled by "the State Pollution Control Boards (SPCBs) and the Central Pollution Control Board (CPCB) in India". "The Ministry of Environment,

Forests, and Climate Change (MoEFC)" has alerted cement plants of a number of environmental laws and regulations, as well as "the Corporate Responsibility for Environment Protection (CREP)" charter. The "National Council for Cement and Building Materials (NCB), MoEFC, SPCB, and CPCB" are important regulating authorities. The cement industry has been indirectly impacted by the Supreme Court of India's periodic requests for the industry to reduce emissions.

➤ Development in Cement Industry to Improve Long-Term Sustainability:

One of the industrial sectors with the biggest emissions is the cement industry, which primarily emits CO₂ through direct as well as indirect emissions. Fuel combustion and calcination are the two primary processes under direct emissions. Fuel combustion is an energy-related emission that occurs when fossil fuels are utilised to heat a rotary kiln or pre-calciner. Thirty to thirty-five percent of the CO₂ emissions produced during the cement production process are attributed to it. "Process emissions," the other primary source of direct emissions, account for between 50 and 55 percent of the CO₂ emissions generated throughout the process. These emissions are caused by chemical processes that break down limestone (calcium carbonate) in the pre-calciner.

The remaining 10–15% of CO₂ emissions come from indirect sources; power/electricity and logistics account for "8–10% and 2–5% of CO₂ emissions", respectively. CO₂ emissions contain the largest portion of greenhouse gas (GHG) emissions—nearly 98–99% of overall emissions—while NO_x and methane emissions are still rather small.

Despite the fact that India's cement sector is faced with a significant decarbonization challenge, it is beginning from a relatively robust position. After iron and steel, cement is India's second-largest industrial greenhouse gas emitter, accounting for about 7-8% of the nation's total CO₂ emissions. This sector is also one of the most challenging to mitigate due to its reliance on fossil fuels for kiln combustion and a substantial portion of process emissions from limestone calcination, which require expensive innovative solutions. Nevertheless, Indian cement producers have already achieved substantial efficiency enhancements in response to this carbon-intensive production profile. The average emission intensity of the sector is 0.60 – 0.65 tonnes of CO₂ per tonne of cement (tCO₂/t), which is near the global average of ~0.6 tCO₂/t. The advancements made in the past decade were the consequence of ongoing investments in the most efficient technologies and the early deployment of waste heat recovery systems (WHRS) that have been demonstrated to be cost-effective. These systems provide an exceptional foundation for the decarbonization of cement production.

Policy initiatives, corporate leadership, and early-stage technology development assistance are fueling the transition to

a low-carbon economy. The cement industry in India is taking a step toward convergence in the transition toward decarbonisation, both regulation and voluntary measures. The MoEFCC6 has also required 186 cement plants to reduce their use of the greenhouse gas emission intensity (GEI) by 2-3% from 2025-27, establishing an accountability level for the cement industry. The targets are modest, but are expected to grow in strength over time. Major firms including UltraTech, Dalmia, JK Cement, and JSW Cement have also stated their net zero transition timeframes, which range from 2040 to 2050. A number of market, economic, and technological obstacles make it difficult to achieve further reductions in emissions. However, India's cement industry has the potential to utilize its existing strengths to emerge as a global leader in incorporating industrial growth without compromising on low carbon growth.

1. Alternative Raw Material:

Blast furnace slag is one of the raw materials that are indispensable to the cement industry for producing the cement variety named "Portland slag cement (PSC) and Portland composite cement (PCC)". It can also be used as a mineral additive and supplementary cementitious material (SCM) for concrete. India is projected to produce 467 crores of tons of cement in FY 2025. PSC was 10%, PCC was 4-5%, and OPC was 22-23%. Hence, it could be expected that in fiscal year 2025, the cement industry would use between 65 and 70 percent of the blast furnace slag produced. Furnace slag consumption will be promoted by the consumption of cement. To decarbonize the cement industry, it is crucial to use GGBS as it can significantly decrease the amount of CO₂ emitted to the environment during clinker production. This is expected to raise the market share of BF slag up to 25–30% of the total demand by fiscal 2030.

2. Alternative Fuel Rate:

The ratio of thermal substitution rate (TSR) indicates the ratio of replacing expensive and CO₂-intensive fossil fuels by alternative fuels (AF). Cement plants are continuously looking for suitable and economical alternative fuels as it is becoming necessary to reduce fuel prices and CO₂ emissions. The Cement Manufacturers' Association (CMA) projected that the percentage of use of alternative fuels in the fuel mix of the domestic cement industry would be between five and six percent in 2021. The international standard was around 15% in 2020, according to the International Energy Agency (IEA).

The Indian government has established a target of increasing the use of alternative fuels in the cement industry to 25% by 2030 to reduce carbon emissions and promote sustainable development. The local cement industry is using modern technology and developing pre-processing platforms to enhance "its infrastructure, capacity and ability" to enhance the TSR. The participants are looking to reduce the carbon footprint and

dependence on fossil fuels by using alternative fuels, including "biomass, refuse-derived fuels, and municipal solid waste".

3. Renewable power:

Rapidly rising energy demand and the government's focus on sustainability are changing the workings of the manufacturing industry; demand for clean energy is growing, such as solar and wind. The total installed base increased from about 290 MW in 2017 to nearly 1500 MW in fiscal 2024, indicating that the installation of renewable energy capacity has really expanded quickly over a low base. The additions, however, were largely in the area of the solar sector and to a lesser extent in the wind sector.

The similar tactic has been used by cement companies. Large and medium-size companies have been keen to develop renewable capacities to keep their energy costs down and carbon emissions to a minimum. In the last decade, India's top 15 cement firms, who together have around 80% of the country's grinding capacity, have made significant investments in WHRS and installed nearly 600 MW of renewable electricity. Moreover, some companies, like UltraTech Cement, have announced their plans for 100% shift to renewable energy by 2050.

4. Waste Heat Recovery System:

One possible way of improving the energy efficiency of a cement plant is to utilize the hot gases generated in the plant. Some of the electricity consumed would be canceled out by the electricity generated, which would reduce the amount of electricity required. To move the energy towards the system and lower energy costs, the cement companies have invested heavily in WHRSs. Large scale players have constructed a considerable amount of WHRS capacity to meet their energy requirements.

5. Substitution of Clinker with Blended Cement:

The use of "blended cement, such as Portland pozzolana cement (PPC), Portland slag cement (PSC), and composite" replaces the main source of CO₂ emissions, clinker, and thus reduces the embodied greenhouse gas emissions. In fact, the emissions are reduced as the cement-to-clinker ratio goes up. It can also be called Green Cement.

A new product is limestone calcined clay cement (LC3). This new type of cement is based on calcined clay and limestone. LC3 is available at a low cost, can reduce CO₂ emissions by up to 40%, and doesn't necessitate the substantial capital investment of necessary changes at existing cement plants. It is produced with low-grade clays and limestone which can easily be found in large quantities. To implement the use of calcined clay technology, JK Lakshmi Cement has tied up with "the Society for Technology and Action for Rural Advancement".

7. DISCUSSION AND ANALYSIS

The analysis reveals that the Indian cement industry is in the midst of a phase of robust demand growth, capacity growth, consolidation and sustainability transition. The key drivers of demand are housing, infrastructure, rural development, urbanisation and government capital expenditure. But the industry also is under pressure from fluctuating fuel costs, steep logistics expenses, competition from other regions, risk of excess capacity, and environmental regulations. Success or failure of the industry will hinge on the ability of firms to achieve a balance between growth, profitability and decarbonisation.

• Interpretations of Findings-

The results show that the cement demand in India is structurally strong as it has low per capita demand, rapid urbanization, demand from the rural population and development in infrastructure. Large players are working on capacity expansion and acquisition of local companies as a way of increasing market share. Meanwhile, margin pressures on power, fuel, freight and raw material costs continue to be huge challenges. Sustainability projects like WHRS, renewable energy, blended cement, alternative fuel, and green cement are gaining significance in terms of being competitive over the longer-term. Hence, the industry is moving from volume-based to efficiency and sustainability-based model.

• Describe how this work compares to previous research and/or literature. Compare this work with prior studies/literature-

In the existing literature on the Indian cement industry, infrastructure development, housing demand, energy intensity and environmental issues are generally cited as some important themes. The results of this paper are consistent with previous studies indicating that government infrastructure investment and urbanisation are important demand factors. Previous works also indicate that cement manufacturing is also energy-intensive and needs cleaner technologies. Nevertheless, this paper builds on this topic by integrating market structure, capacity growth, costs, RMC demand, consolidation and sustainability in a comprehensive framework. Thus, it offers industry-wide analysis and insight rather than demand analysis or environmental analyses.

• Originality and Theoretical Contribution-

This study is novel in the sense that it connects the growth paradox of the cement industry with the concepts of sustainability and structural transformations. The paper elaborates on the fact that the same industry that provides economic development also poses environmental problems. It does it theoretically by looking at the cement industry from three interconnected perspectives – growth drivers, market consolidation and green transition. This integrated approach allows the understanding of the energy efficiency, carbon

reduction, circular economics and the regulatory alignment that will be the qualities necessary for industrial competitiveness in the future, in addition to production capacity and market share.

- **In what ways are your research methods strong? What are your strengths in research?**

The key strength of this research is the fact that it covers the Indian cement sector in all aspects such as demand outlook, capacity addition, value chain, cost, RMC market, growth drivers, challenges, sustainability initiatives etc. Analysis is relevant and timely so that it uses secondary data that is produced recently from industry reports, government documents, and company documents.

There are some limitations in the study, however. It primarily uses secondary data, and the accuracy of the information is limited by the accuracy of published data. The study is more of macro level industry level research, and does not in-depth analysis of the financial performance of the company. Findings would have been further strengthened by primary data from industry experts, cement companies, dealers and consumers. Econometric analysis, a comparison of the profitability of companies, and a survey-based evaluation of sustainable practices can be done in the future.

8. CONCLUSION

The Indian cement industry is one of the important pillars of the economic development of India, helping in building infrastructure, housing and industrialisation. Additionally, urbanisation. The sector is expected to grow long term at a steady pace in line with the growth of public infrastructure investment and real estate activities. In addition, the increasing demand for construction in rural and urban areas. Meanwhile, the industry is making structural changes, with capacity growth, market consolidation and technological innovation. Additionally, greater emphasis on sustainability. A range of issues like fluctuations in input prices, pricing pressure and environmental measures, however. Besides, government capital spending delay remains a drag on profitability and the long-term fundamentals of the industry remain solid. For the future, digital transformation and operational efficiency as well as the use of green technologies will become the decisive factors. Also, conforming to changing environmental laws.

- **Summary of Key Findings –**

The study reveals that India is the second largest cement producer in the world and the demand is expected to rise steadily in the upcoming years. Infrastructure development, urban and rural residential construction, industrial growth. Further, the PM Gati Shakti, PMAY and Smart Cities Mission are the key drivers of demand from the government. Mergers and acquisitions create industry consolidation, enhance economies of scale. Major initiatives for sustainability such as

renewable energy, alternative fuels, waste heat recovery systems (WHRS) and blended cement. Also, the use of clinker alternates helps to cut down carbon emissions and enhance the long-term competitiveness. In spite of short-term problems of rising energy prices and the scarcity of energy. Further, the sector continues to be strong for sustainable growth due to environmental compliance.

- **Provide answers to Research Questions –**

The study identifies that the factors that are major contributors to the development of the Indian cement industry are infrastructure, housing demand, urbanisation and industrial development. In addition, government policies which support. The major obstacles are the fluctuating prices of raw materials and fuels, price pressure, and excessive capacity in some areas. In addition, the strengthening of environmental regulations. Moreover, the study reveals that technology innovations like Renewable Energy Integration, Digital Manufacturing, Alternative Fuels, Blended cement, and Technology are significant. Further, waste heat recovery systems play an important role in enhancing the sustainability and competitiveness in the long-term.

- **Recommendations for future research and policy-**

Future study is suggested to be directed towards the financial performance of the companies, demand forecasting in the region and carbon emission benchmarking. In addition, the economic viability of new technologies, eg. Carbon Capture, Utilisation and Storage (CCUS). Econometric models and primary survey data can also help provide supporting empirical evidence to researchers. In a policy perspective, the government should continue to invest in infrastructure, encourage the use of blended and low-carbon cement, promote the implementation of renewable energy and make policies more comprehensive to improve waste utilisation, and strengthen multimodal logistics infrastructure. Further, promote research and innovations in green cement technologies.

- **Broader Implications**

The results hold significant meaning for policy makers, industry players and investors. Additionally, researchers. India's sustainable development and national commitment to climate change will rely on a sustainable and technologic cement industry in order to achieve the goals of its infrastructure. It shows that growth and environmental sustainability are not mutually exclusive, rather they can work together in innovative and efficient ways, that utilize resources. Furthermore, public policies that support. The move towards lower carbon cement will boost the competitiveness of the

industry in the global cement market and help India achieve the long-term goal of sustainable and inclusive economic growth.

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