The Benefits and challenges of Building Industrial Autoclaves in China for export

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Introduction

Building an autoclave is a daunting task for any engineer as autoclaves are inherently dangerous machines capable of high pressures, and require serious considerations around safety interlocks, pressure relief design, and other important safety design parameters. Furthermore, an industrial autoclave can be large and therefore its raw materials are expensive with little margin for waste or error during fabrication. Competence in hazard analysis and safety interlock design using back-up relays to supplement programmable logic controllers (PLCs) and microprocessor controllers (MPCs) requires collaboration between electrical, signaling, mechanical and programming engineering disciplines making for the formation of a special team of skilled professionals, this being a minimum requirement before proceeding with any design or build of an industrial autoclave. Finally, as autoclaves require a deep understanding of ASME Section VIII, Div. 1 or AD2000 codes of construction, only a few mechanical engineers possess the skill and expertise to both design and build such hazardous equipment skillfully and with enhanced safety being integral to its design.

It is a well known fact that in the past decades China has become an industrial powerhouse. This is no accident, and central and local planning of cities, its high rises and buildings has necessitated advances in building technologies. Rapidly, entire cities have been constructed atop newly built railway stations, and in planned communities that have the capacity to house millions. These sorts of developments have relied upon agile construction teams, building technology advances and creative and efficient construction methods in order to complete safe, affordable and efficient modern buildings as the Chinese population has become ever more affluent and populous.

One such technological advance in the construction industry is the invention of Autoclaved Aerated Brick (AAC). This light weight brick permits tall buildings to be constructed without the need for deep excavation of foundations or significant pile driving activities. Due to AAC's inherent light weight, tall buildings are subject to lower foundation level torques in high winds, and therefore require less support underground than traditional heavy concrete or masonry brick constructions. The AAC revolution in China has been one of the primary features and drivers of the high speed development of high density high rise buildings in China over the last 20 years of incredible advance and growth in China.

According to Wikipedia, Autoclaved Aerated concrete (AAC) is light weight precast, foam concrete building material suitable for creating masonry blocks. It is composed of quartz sand, lime, cement, gypsum, water and aluminum powder. AAC products are cured under heat and pressure in an autoclave. AAC's advent dates back to the 1920's. Swedish architect Dr. Johan Axel Eriksson working with Professor Henrik Kreüger at the Royal Institute to devise AAC. AAC has advantages over standard masonry brick deriving primarily from its light weight. For example, supporting steel costs can be reduced by 15%, construction can be sped up due to AAC's light weight and ease of cutting and shaping. In addition, AAC is by virtue of its autoclaved design uniform and consistent throughout with no stones or pebbles to interfere with cutting and shaping. In addition walls can be made thinner due to AAC's low thermal conductivity of 0.16 to 0.18 W/m-k which reduces air-conditioning loads by around 30%. Fire resistance is enhanced by AAC over brick with up to 4 to 6 hour fire resistance making AAC suitable where fire safety is a high priority. Finally, efflorescence that derive from sulphates present in the inorganic constituents of earthen brick is not present in the sand/ash used to react with Lime and cement to form AAC in autoclaves. These are only a few of the benefits of AAC.*

It is no surprise that AAC has played an instrumental role in the construction boom that continues in China and is increasingly being exported by China, and in turn, the demand for AAC autoclaves to be exported from China.

CONSTRUCTION IN CHINA

The Tall Buildings Council[1] reported that of the 143 buildings taller than 200m that were completed in 2018 of those 109 were built in Asia, with 88 in China. China has built more super tall buildings over 200m than the rest of the world combined. In 2018 the CITIC tower was completed –

standing at 527m high, it is the tallest building in Beijing and the eighth tallest building in the world. Further evidence for China's propensity for high rise construction can be found in a report compiled by Lodging Econometrics[11] which found that China's total construction pipeline related to hotel construction increased by 15% by projects and 8% by the number of rooms. The report revealed that there are now 2,845 projects and 590,809 rooms in the construction pipeline. In terms of cities, Guangzhou has the highest amount of hotel construction work in the pipeline, followed by Chengdu, Suzhou and Hangzhou.

GLOBAL INFRASTRUCTURE DEVELOPMENT

The Belt Road Initiative (BRI), also known as the silk road project, is of great important to China as construction growth begins to stabilize to 4.5% over the next five years.[2] Due to this stability of growth China is forced continue to feed its industrial base so that growth can accelerate, and prosperity continue. Wanchun Zhou, vice president at Sany Heavy Industry, a construction equipment exporter, told International Construction news[12] that around 70% of the firm's overseas sales come from the BRI. Sani reported that one of the key things the BRI had done was to get more people using Sany equipment; he commented that there has previously been a bias against China-produced equipment, with people thinking that the quality is not high. The BRI policy has given other countries a chance to know China and China's products and technology. The biggest contractors in China have worked in these big projects overseas and this has improved China sales in overseas markets. The BRI policy has helped to bring Chinese products to work sites around the world. The more that people use Chinese building products the more confident they become with them. It is estimated that China has invested US$210 billion through BRI, the majority in Asia, although there are signs that co-operation with European countries may increase. Italy recently became the first G7 member to conclude a BRI agreement.

According to Research and Markets [3] The global autoclaved aerated concrete (AAC) market size is projected to grow from USD 18.8 billion in 2020 to USD 25.2 billion by 2025, at a CAGR of 6.0%, between 2020 and 2025. The major driving factors include the increasing urbanization & industrialization, growth in the infrastructure sector, rising demand for lightweight construction materials, growing preferences for low-cost houses, and an ever-increasing focus on green & soundproof buildings. These factors are driving the market. However, the cost associated with AAC and the lack of awareness is expected to restrain this market. Focus on construction projects with a high affinity for earthquakes, and low market penetration is expected to offer significant growth opportunities to the AAC manufacturers.[5]

CHINA EXPERTISE IN AUTOCLAVES

A google search for global autoclave suppliers including non-AAC autoclaves shows China as the leading exporter. For example, China eclipsed top suppliers such as Germany and Israel in 2020 by doubling their combined exports of supply to India totaling over $19m in sales.[13] China is a technological leader in the supply of autoclaves to non-western markets such as India, but lag in North American and European markets as data is scarce on their import.

COST AND INGENUITY

The leadership of Chinese brand suppliers should come as no surprise given the foregoing explanation of the construction demands for AAC brick in China itself over the past two decades[4]. For instance, the percentage of urban population in Asia Pacific is likely to increase from 37% in 2000 to 62% by 2020, and this is likely to create need for new construction, thereby propelling the autoclaved aerated concrete market. The primary energy needed to produce a cubic foot of AAC (raw materials, manufacturing, and transport) is relatively low compared to that for alternative masonry building materials.[6]

LEAPS AND BOUNDS

With demand for autoclaves from China and within China comes rapid growth in expertise and in application experience within Chinese industry. This expertise makes China the powerhouse of autoclave production in the world today, and in the foreseeable future.

One additional advantage of China is the cost of materials. Autoclaves require steel and the biggest steel producing country is currently China, which accounted for 53.3% of world steel production in 2019 and more in 2020. This means that the price of steel is lower domestically in China, and more available without middlemen and appreciable transportation than in any other country in the world.[7]

Another Chinese advantage when building autoclaves are lower labor costs. Although China is not the lowest labor cost center in the world due to its continual middleclass growth and improved wealth distribution, its relative advantage related to labor costs cannot be ignored as an advantage when compared to other developed countries capable of producing complex equipment such as autoclaves. For example, China's labor cost is only 72% of Canada's or Germany's, and 70% of the United States.[8]

With cheap labor and cheap materials in China, and the high volume requirements for AAC brick and AAC autoclaves, the technical expertise developed within China has only grown concomitant with its industrial growth.[9] Autoclaves are no exception, and with the increased dependence upon China to supply the world's autoclaves, and the rise of AAC brick as a viable southern hemisphere construction material, the expertise of China will only continue to increase.

However, the type of autoclave construction expertise and process of construction in China differs substantially from that of Germany or USA, Canada or Israel, for example. As a case in point, with an estimated 700 million of its billion or so residents now residing in urban areas, China has reached an important tipping point in its evolution from an agrarian to industrial economy. China has built more than 500 empty cities since the cultural revolution in 1978, with hundreds more set to come online by the end of the decade. The theory behind it is solid; by 2020 one in eight humans will live in a Chinese city, totaling more than one billion people. China's existing urban infrastructure simply cannot support that kind of population boom. The new city of Tianducheng in Hangzhou is perhaps the most easily recognizable of the country's ghost cities, what with the 300-foot tall, 1:3 scale replica of the Eiffel Tower dominating the skyline and all. In fact, most of this upscale luxury real estate development mimics the design of Paris—just with a fraction of the population.[10]

At the afore mentioned pace of growth, and with the supply of AAC autoclaves in high demand, supply of an autoclave by an autoclave manufacturer in China is less the supply of a finished product with all bells and whistles included, than the supply of a process of building an autoclave in a half-built state that is completed on-site by a skilled installation teams. This autoclave manufacturing approach differs vastly from that of North American manufacturing of autoclaves whose finished products are completely functional before leaving the factory and are almost ready for plug and play at delivery. China's necessary 'on-the-fly' or as North Americans would say 'seat of the pants' approach to manufacturing is not wrong, but merely more suitable to a fast-paced construction environment that requires a high degree of onsite ingenuity and skill. Chinese autoclave manufacturers typically develop highly capable trouble shooting teams, on the fly, with a flexible and mobile teams of site configuration specialists who put together autoclaves in stages and in a manner tolerated by Chinese end users. The genius of on-site assembly lies in the incredible flexibility of China's work force, its lower bar related to standardization enforcement, and its relatively weaker labor work force rights. That being said, there is no doubt in the expert levels of skill and know-how that are widely present in Chinese Autoclave manufacturing operations.

A different successful and widely known example of site-level construction of complex systems (by necessity) is the vast and rapid growth high speed driverless railway in China. Over the past decade, China has built 25,000 km of dedicated high-speed railway—more than the rest of the world combined. What can we learn from this remarkable experience? China's High-Speed Rail Development examines the Chinese experience to draw lessons for countries considering investing in high-speed rail. Planning and delivery mechanisms that enabled the rapid construction of the high-speed rail system is a distinctly present day Chinese methodology, and has come under some scrutiny for its seat-of-the pants approach. It highlights the role of long-term planning, consistent plan execution, and a joint venture structure that ensures active participation of provincial and local governments in project planning and financing whenever export is involved. Traffic on China's high-speed trains has grown to 1.7 billion passengers a year. One of the most remarkable aspects of the Chinese experience is the rapid pace of high-quality construction.[10]

WORKING OUT THE KINKS

In a world where travel is restricted due to COVID-19, politics, or climate change, to name a few barriers to trade, building autoclaves in the way China is accustomed to (on the fly and on site) cannot be a sustainable approach to manufacturing for an increasingly larger Chinese export market. Building a complete autoclave with all the bells and whistles that is easy to unload from a container, and easy to connect is by far the preferred option for any buyer and reduces the risk of downstream delays due to reliance on staff to complete the work in situ. Furthermore, working out the kinks in a design is always more effective at the Chinese manufacturer's venue, and has the added benefit of a cheaper build and test process in a familiar factory setting with full test resources, rather than remotely. This at-home approach to building autoclaves has the potential of saving both manpower allocation, time, and ultimately total cost of the build. This is one way Chinese autoclave manufacturers can stay competitive with Western suppliers of autoclaves.

Another approach to ensuring that the delivered autoclave is plug and play which has been used with success by Titan Research Group Supply is to develop relationships with third party quality control groups within China who can oversee production at the autoclave manufacturer's venue from the very start of the production process to finish and all the way to the port of shipment.

A second method is to only use ASME U Stamp facilities but to supplement with third party ASME authorized inspectors with proper valid credentials, control experts in the field of safety interlocks, and electrical engineers to supplement

the work of the autoclave manufacturer. Performing what would be expensive inspection protocols such as full radiography is also very cost effective and highly recommended in China, where it can be prohibitively costly in countries like USA, Canada and Germany for reasons this paper will not explore.

Another method used with success to developing plug-and-play autoclaves in China is to develop robust factory acceptance test procedures (FATs) that form part of the supply contract and are attached to milestones for payment. This is not intuitive to most Western buyers who are more accustomed to adding terms like liquidated damages for delays or penalties for incompleteness to standard contracts. These latter methods seem to have little effect on the workmanship and completeness of an autoclave build coming from China, especially given the work-in-progress or on-the-fly approach that is so firmly part of the autoclave manufacturing mind-set of many China autoclave manufacturers.

CONCLUSION

In conclusion, there is no doubt that building an autoclave in China is more cost effective, faster, able to be more thoroughly quality controlled and can result in a stronger and longer lasting construction than building an autoclave in North America or Europe. However, keeping on top of the cultural differences that have evolved at autoclave manufacturers in China versus autoclave manufacturers in North America is paramount, and experienced consultants in this field, such as Titan Research Group Supply should be consulted prior to buying any industrial autoclave from a Chinese supplier. There are always exceptions to the rule however and the guiding principle behind any well considered purchase is caveat emptor.

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