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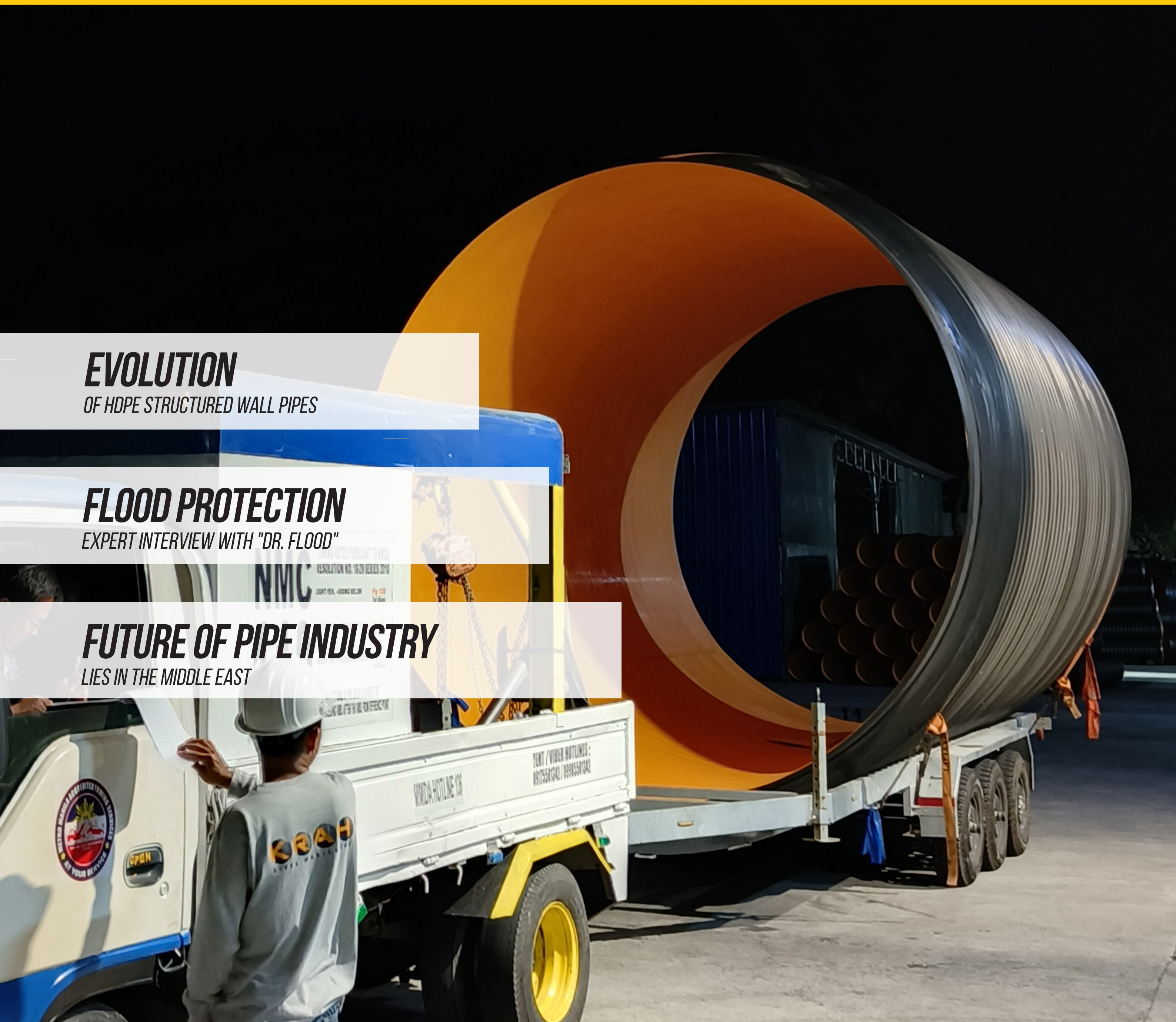

EVOLUTION
OF HDPE STRUCTURED WALL PIPES

FLOOD PROTECTION
EXPERT INTERVIEW WITH "DR. FLOOD"

FUTURE OF PIPE INDUSTRY
LIES IN THE MIDDLE EAST

Content

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Dear Reader

As another eventful year draws to a close, we take a moment to reflect on the challenges, milestones, and successes that have shaped 2024. Despite global economic uncertainties and the ever-changing landscape of the industry, we are proud to report that our order books remain full, a testament to the trust and loyalty of customers like you. Your unwavering confidence drives us to keep innovating and delivering excellence in every project.

Looking ahead, 2025 promises to be an exciting year filled with new opportunities and collaborations. We are kicking off the year with our participation in Arabplast 2025, the premier trade fair for plastics, petrochemicals, and rubber, held in Dubai this January. It's a fantastic opportunity to connect with industry leaders, explore emerging trends, and showcase our latest innovations.

In March, we are excited to gather with partners and peers at the Krah Community Meeting in Egypt. This event has become a cornerstone for fostering collaboration and exchanging ideas within our specialized field.

Further down the line, in October, we will once again participate in K 2024 in Düsseldorf, the world's leading trade fair for the plastics and rubber industry. This major event offers a platform to highlight our advancements and to engage in the critical discussions shaping the future of our sector.

While the industry continues to face supply chain pressures, energy challenges, and fluctuating market conditions, we are proud of our ability to adapt and stay resilient. Our commitment to quality, sustainability, and customer satisfaction remains at the core of everything we do.

As we wrap up the year, we extend our heartfelt gratitude to you—our customers, partners, and friends. Your support makes all this possible, and we are excited to continue this journey together.

Wishing you and your loved ones a joyful holiday season and a prosperous start to the new year!

Evolution of HDPE Structured Wall Pipes for No

The road map from a niche product to being a market staple

Introduction

The development of HDPE structured wall pipes for non-pressure and low-pressure applications illustrates a significant transformation of a niche product in the 1960s to an essential component in the infrastructure industry today. This paper mainly focuses on HDPE structured wall pipes that are produced using helical or radial extrusion techniques which enabled the creation of large-sized pipes. The paper is excluding structured wall pipes produced by corrugators. Furthermore, the paper delves into the evolution and refinement of HDPE structured wall pipes, emphasizing the technological advancements and design improvements that have driven their widespread adoption. With a focus on Western Europe, renowned for its leadership in material science and engineering, this study examines the key factors contributing to the success and growth of these innovative piping solutions. By tracing their journey from inception to their current status as essential components of modern infrastructure, this paper provides an overview of the progress and future potential of HDPE structured wall pipes.

An HDPE structured wall pipe is a type of plastic pipe designed to maximize structural integrity while minimizing material usage. The basic idea behind its structure is to leverage the moment of inertia of the pipe wall, creating a stiff yet flexible system. This design results in a robust pipe that uses less material compared to solid wall pipes, in respect to external loads, enabling it to be a suitable material for drainage and sewage systems. HDPE structured wall pipes have a profiled or corrugated exterior to withstand external loads and a smooth inner surface to maintain efficient flow. The winding process of producing these pipes eliminates the sagging problem as the diameter and wall thickness increases which is the opposite case for solid wall pipes. Standards like DIN 16961, ASTM F894 and EN 13476 govern their specifications, ensuring they meet rigorous quality and performance criteria.

Early Development

The journey of HDPE pipes began in the 1960s and 1970s, marked by the increasing use of thermoplastics in various industrial applications. Initially, HDPE pipes were solid-wall constructions, effective but not fully optimized for performance. The concept of structured wall pipes emerged to improve the strength-to-weight ratio by incorporating profiles and corrugations. The DIN 16961 stood out as a pivotal document, ensuring consistency and reliability in the production of thermoplastic pipes with profiled walls and smooth inner surfaces.

Standardization and Technological Advancements

Introduced in 1977, DIN 16961 provided comprehensive guidelines for classifying, sizing, and specifying structured wall pipes as a complete piping system with fittings and jointing methods; which specifies dimensions using inside diameter to compete with the conventional non-pressure concrete material for drainage and sewer. It laid the foundation for their widespread use in various non-pressure to low-pressure applications, ensuring stringent quality and performance criteria suitable even for public tenders.

The majority of standards governing structured wall pipes specify the nominal diameter as the inside (hydraulic) diameter which is marked as DN/ID. This approach aligns more closely with concrete and other sewage pipe systems, ensuring compatibility and ease of integration with existing infrastructure. By using the inside diameter as the nominal diameter, the standard ensures that pipes will have the same hydraulic capacity, regardless of their structured wall characteristics.

During the 1980s and 1990s, advancements in extrusion technology allowed for the production of more complex and efficient structured wall pipes. Structured wall pipes provided superior stiffness and strength, ideal for demanding underground applications which allowed for the production of larger diameter pipes up to DN/ID 3000 mm. As HDPE pipe technology advanced, DIN 16961 was periodically updated to incorporate new manufacturing techniques and materials, maintaining its relevance and reflecting the latest technological advancements.

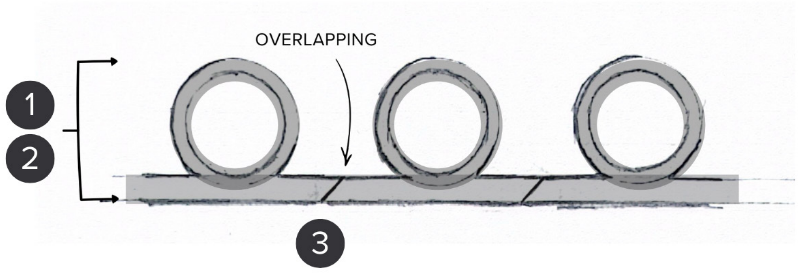
on-Pressure and Low-Pressure Applications

Various production of spirally wound HDPE structured wall pipes

High-Density-PolyEthylene (HDPE) structured wall pipes are known for their versatility, durability, and adaptability across various applications. The following is a detailed comparison of five main different types of structured wall HDPE pipes and their respective production processes; Following named as Type "B" pipe, Type "W" pipe, Type "H" pipe, Type "DWC" pipe and Type "K" pipe, highlighting their production methods and characteristics.

In the sketches below, the symbol (1) represents the structured wall profile, which refers to the engineered shape or design of the pipe's profile that provides strength and flexibility. The symbol (2) is the waterway, which is the smooth inner surface of the pipe that facilitates efficient fluid flow. The symbol (3) indicates the overlapping section, a key feature in spirally wound pipes where the profile overlaps during production to ensure a tight, secure and homogeneous structure. And lastly, the symbol (4) marks the welding part, where the pipe profiles are welded together to achieve a homogeneous and leak-proof joint.

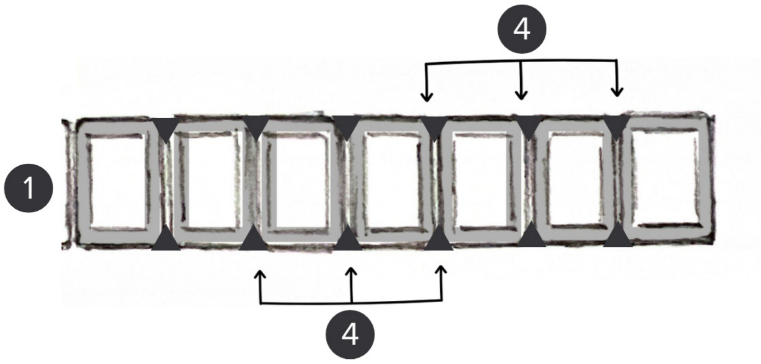
1. Type "B" pipes are made using a single extruder that produces an Omega shape which includes the profile and the waterway (1,2). This profile is spirally wound around a mandrel, with the waterway (3) overlapping between each profile. This approach achieves an excellent balance of efficiency and cost-effectiveness while focusing on practical production methods. Type "B" pipes are produced by batch-production and with the possibility of integrated socket and spigot ends.



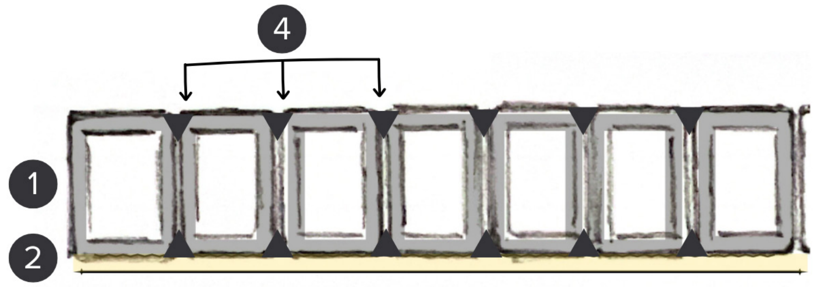
Sketch 1: Type "B" pipe cross section is a single Omega profile (1,2) with overlapping (3) in the middle section of each profile

2. Type "W" pipes are created using a continuous process where a rectangular profile (1) is produced from a main extruder (profile extrusion) and will be spirally wound around a roller system. Welding (4) is done both inside and outside of the pipe, ensuring homogeneity and durability. This process leaves the inner surface not as smooth as the other pipe types due to internal welding on every seam. Integration of socket and spigot is difficult, but pipe length is more flexible.

3. Type "H" pipes follow a two-step process: first, a rectangular profile (1) is produced from the main extruder, same as the Type "W" pipe. Another extruder will produce a smooth waterway (2) on a rotating mandrel. The extruded rectangular profile will be spirally wound on the waterway. Accordingly, the seams outside of the pipe will be subjected to welding (4) as the profile spirally wound around the mandrel. These combined processes will result in a structured profile with a smooth inner surface. Socket and spigot can be produced with mandrel technology.

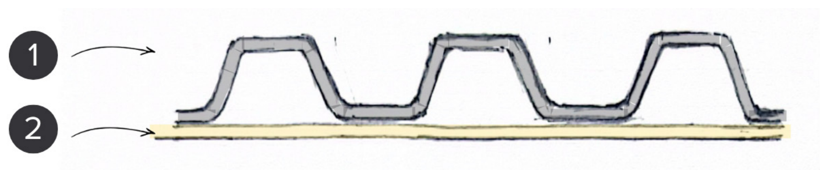


Sketch 2: Type "W" pipe cross section is composed of a rectangular profile (1) with welding-seams (4) both inside and outside of the pipe in-between profiles



Sketch 3: Type "H" pipe cross section is a rectangular profile (1) with a smooth surface waterway (2) and welding-seams (4) between profiles

4. Type "DWC" pipes consist of a smooth inner wall (waterway (2) and a corrugated outer wall or profile (1). Two extruders are used: one forms the corrugated profile by molds, and the other creates the smooth waterway. These layers are fused during production.



Sketch 4: DWC-pipe cross section is a fusion of a profile (1) and a smooth waterway (2)

5. Type "K" pipes stand out for their advanced co-extrusion technology. Three extruders are used to form the profile (1), waterway (2), and inner color layer. These components are helically wound on a mandrel, melting together to form a homogeneous and seamless structure. The waterway overlaps beneath each profile for added strength, and the pipe is cooled at ambient room temperature to minimize internal stress. The modular extruder set-up allows for high flexibility to customize the pipe profile from changing the waterway thickness to creating different profiles with varying moments of inertia as needed. The Type "H" and Type "W" methods incorporate socket and spigot joints, enabling them to handle low-pressure ratings.

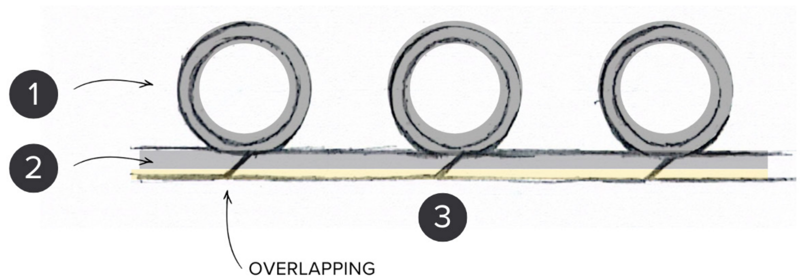
These designs enhance the versatility and application range of structured wall pipes, making them suitable for various infrastructure needs.

Modern Innovations and Widespread Use

The most recent major update of DIN 16961, in August 2018, introduced modern testing methods for ring stiffness and pressure resistance. It expanded the scope to include helically wounded pipes, reflecting the growing market demand for larger diameter pipes. Internationally, many derivations of the German standard DIN 16961 have been created to facilitate the use of the pipe system globally. Standards such as NBR7373 in Brazil, ASTM F894 in the United States, and the Japanese Standard, JIS K 6780, have been developed based on DIN 16961. These derivations ensure that the high-quality and performance criteria of structured wall pipes are maintained across different regions, promoting consistent and reliable use in various non-pressure and low-pressure applications worldwide.

The most significant technological advancement occurred when Krah GmbH and Bauku GmbH eventually parted ways in the early 90s in which Krah focused on technology and machine manufacturing. Following this separation, Krah GmbH successfully formed a new partnership with the German Frank GmbH. This new collaboration allowed Krah to continue advancing its technological innovations and machinery while leveraging on Frank's market presence and expertise to implement the new developments in the pipe market.

Early in this partnership, the integrated electrofusion technology was developed and introduced to the market. This innovation combined the ease of socket/spigot jointing with the major benefits of HDPE weldability. Using the same production technology, the socket and spigot together with the fittings (bends, reducers, and branches) are produced as solid walls which ensures proper segmenting during fabrication. Additionally, the production technology was enhanced by incorporat-



Sketch 5: Type "K" pipe cross section with customizable profile design (1) and waterway thickness (2) where overlapping (3) of waterway is underneath each profile

ing an additional co-extruder, enabling the production of a "bright" inspection-friendly inside surface. Moreso, the production process became more automated and the production flow was optimized, enabling batch production to manufacture pipes with significantly increased cost efficiency. The change over time was drastic, efficiently shortening the time needed to switch the production of a DN/ID 1000mm SN4 pipe to a DN/ID 2000mm SN8 pipe to only 20 minutes with nearly low to zero starting scrap. Following this, the technology allows the production of tailor-made pipes with customized stiffness levels according to customer specifications and order. This process is similar to 3D printing which exemplifies the cutting-edge capabilities of modern manufacturing, offering unparalleled flexibility and efficiency.

The structure of the pipes continuously improved, resulting in lighter pipes and increased production output, even for large diameter pipes. With a tailor-made production, overdesigning the pipes will be avoided. Today, the profile wall of structured wall pipes could be design with a smooth interior, a profile that could be in multiple layers and with a top layer (close profile) to increase the stiffness of pipe as the diameter increases. This led to a significant reduction in costs per meter. One main contributor of decreasing the pipe weight is the continuous development of increasing the pipe profile height which yields to a higher moment of inertia. This allows a pipe to have the same stiffness but with a lighter weight. Hence, the pipe uses lesser raw material. Additionally, the homogeneous waterway wall enabled the pipes to be effectively used even in low-pressure applications. Nowadays, reducing the CO_2 footprint is achievable by using the optimal amount of material in production. The approach to reduce the material before reusing and putting recycling as the last resort will not only conserve resources but will also decreases the energy required for manufacturing, transportation, and installation, leading to lower overall greenhouse gas emissions. By optimizing material use, industries can contribute significantly to environmental sustainability and carbon footprint reduction.

HDPE Structured wall pipe as a market staple

From a niche product initially used for specialty applications, HDPE structured wall pipes have become a standard in infrastructure projects. The (real) production output has increased dramatically from around 200 kg/hr in the 1980s to approximately 1500 kg/hr in 2024. This growth is attributed to advancements such as the transition from manual to fully automated production and the integration of co-extrusion technology, allowing efficient production of larger-sized structured wall pipes.

The growing demand for production lines of HDPE structured wall pipes is evident in Krah's output: in the 1980s, Krah produced one machine every two years, but by the 2020s, they were producing 3-5 machines annually. There has also been a significant shift in the diameter of the pipes produced. Today, 60% of all mandrels (production tool) are for pipes greater than DN/ID 1200 mm, whereas in the past, the majority of pipes had diameters less than DN/ID 1200 mm.

HDPE structured wall pipes are expected to find new applications, particularly in areas such as renewable energy (e.g., hydropower plants), agriculture (e.g., irrigation systems), and disaster management (e.g., flood control systems). The versatility and adaptability of these pipes make them suitable for a wide range of emerging needs (Lee & Wang, 2023).

Today, the largest HDPE structured wall pipes have diameter of up to DN/ID 4000 mm with projects under design phase of up to DN/ID 5000 mm. These pipes are finding attractive applications in marine pipelines, drinking water reservoirs, the headrace of hydropower plants, and large-scale flooding control systems.

Krah technology alone has spread to over 30 countries across six continents, including Germany, Norway, Sweden, Denmark, Poland, the UK, Italy, Spain, Russia, the USA, Argentina, Chile, Mexico, Iran, Saudi Arabia, Algeria, Egypt, Turkey, Estonia, Australia, New Zealand, Philippines, Malaysia, and more. Countries like Indonesia, the Czech Republic, and South Africa are expected to follow by the second half of 2024.

Conclusion

The advancement of HDPE structured wall pipes for non-pressure to low-pressure applications is intricately connected to the development and continuous refinement of international standards and acceptance of the pipe system, backed up with successfully realized large pipe projects (worldwide) from the 1960s up to present. With ongoing progress in material science and manufacturing technologies, HDPE structured wall pipes are poised to achieve even greater enhancements in performance and sustainability, solidifying its role as a fundamental component of modern infrastructure—specially with a unique integrated electro-fusion socket in the pipe for jointing.

With the further development of large size production, innovative material-saving applications, and a focus on sustainability, the future of HDPE structured wall pipes is highly favorable. Customized to meet specific client needs, these versatile pipes are expanding their use across sectors making it a significant market staple product with consistent market demand. Technological advancements are making them more cost-effective and optimizing performance. HDPE structured wall pipes present a highly efficient alternative to traditional pipe materials (e.g. concrete and metal) offering a cost-effective, adaptable and eco-friendly solution for infrastructure projects. This efficiency means that with the same government budget, it is possible to lay down longer pipelines compared to using conventional materials like concrete or metal. By opting for HDPE structured wall pipes, governments can maximize their budget, extending the reach of essential services such as water supply and sewage systems to more communities.

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From Technology to Community: Join Krah's Digital Journey

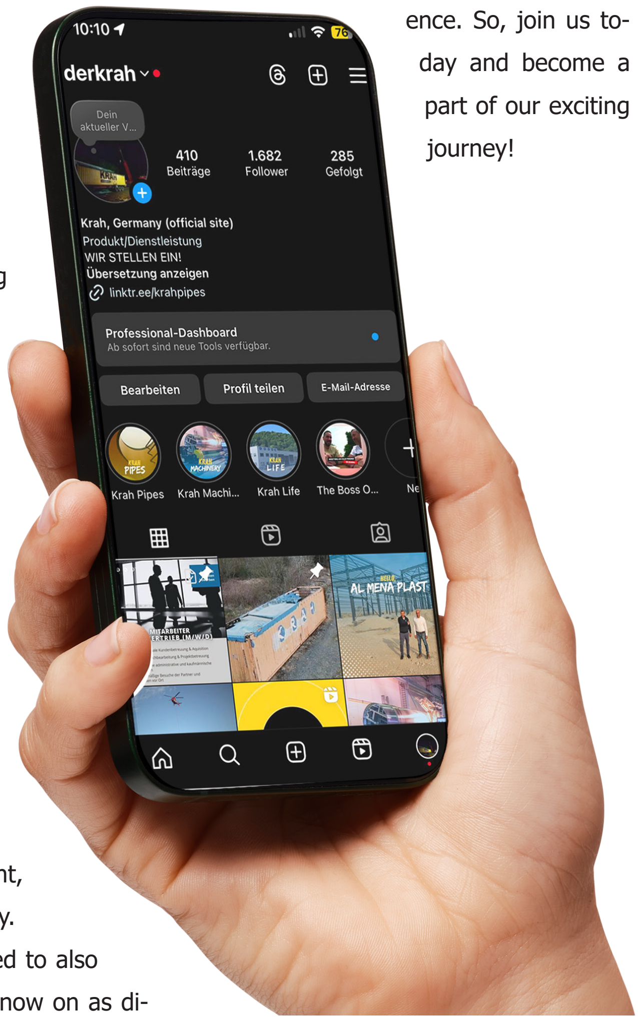
Social media is a game-changer, even for industries as specialized as machine manufacturing. If you're passionate about cutting-edge technology and want to learn more about KRAH's innovative solutions, our social media platforms are where you need to be. Across Instagram, YouTube, and LinkedIn, we share valuable insights, engage with our audience, and highlight the incredible engineering behind our products - and now we are even reachable on "X"!

On Instagram (**@derkrah**), with 1,400 followers and counting, we provide a visual journey into the heart of our operations. From showcasing our advanced machines to featuring behind-the-scenes content, this platform is perfect for those who love a mix of technology and storytelling. It's no wonder our followers come from diverse countries like Germany, the USA, and Brazil, making it a truly global community.

For a deeper dive into the technology, our YouTube channel (**@krahtechnology**) is the ideal destination. With over 1,000 subscribers, we bring theories to life through videos demonstrating Electrofusion technology, extraordinary durability tests, and real-world applications on construction sites. Each video is crafted to educate and inspire, but we need your input—your comments, likes, and shares not only guide our content but also ensure that the platform's algorithms help us reach a broader audience.

LinkedIn (**@krahpipes**) is where business and innovation intersect. Our 1,300 followers leverage this platform to stay connected to industry trends, network within the Krah Community group, and gain insights from events like trade fairs. It's an essential tool for professionals who want to stay informed and engaged - however, we have the feeling that LinkedIn is becoming more and more a second "Facebook", losing its simply informative and business-related content.

Social media isn't just for consumer brands; it's a crucial tool for industrial companies too. For machine manufacturers like KRAH, platforms like these allow us to bridge the gap between complex engineering concepts and everyday understanding. They humanize our brand, offer an avenue for customer feedback, and provide a cost-effective way to showcase innovations. Moreover, as digital marketing evolves, social media is becoming a key driver of business growth—whether through targeted recruitment, customer engagement, or enhancing global visibility. That's why we have decided to also use the platform "X" from now on as direct link to our customers and our Krah community. Under **@krahcommunity** you will have the chance to get in direct touch with us-for us at the moment the easiest way to communicate with everyone. By following us on Instagram, YouTube, LinkedIn and X, you're not just staying updated; you're joining a community of innovators. Your interactions, whether it's a thumbs-up, a question, or a share, help us grow and improve. Together, we can elevate the conversation around manufacturing technology and bring KRAH's mission to a wider audience. So, join us today and become a part of our exciting journey!



The future of the pipe industry lies in the Middle East

Interview with Mr. Khaled Al Hashani

Dr. Alexander Krah meets up with an old friend

Alexander: Khaled, my good friend, where have you been the past 4 years? How are you today?

Khaled: Hello Krah Community! I am so happy to meet you again after all these years. The Covid period shut us down for a long time, we were waiting for the Abu Dhabi factory to start, we spent 4 years of waiting, now it is running and working, thanks to your people – I want to say a special thank you to all engineers and workers involved. Today, I am working in a different way than I did in the past. My son Mohammed is now taking care of the Saudi factories, I am now taking care of new businesses in Saudi and Dubai, following the vision of our Crown Prince HRH Mohammed bin Salman al-Saud, which is Saudi 2030.

Alexander: Thank you. Khaled, it seems that something has changed in the Middle East, Dubai is suddenly so green? Also, the government spent a huge amount of money for drainage, why?

Khaled: The Government here allocated 8bn$ for a huge stormwater project. After the unprecedented flooding 2-3 months ago, they are planning to build a stormwater runoff system.

Alexander: That is a huge amount of Money. Overall, it seems like there is lots of money flowing in Saudi. Khaled, despite we are meeting in Dubai, you said you preferred Abu Dhabi. That's also where the plant is located. Why is it that way?

Khaled: Abu Dhabi is the capital, that's where the money is. Where we have a joint venture with one of the big business men in Abu Dhabi, the business situation and the money is simply better than in Dubai, that's what we believe.

Alexander: Can you understand why many German companies, especially since Covid, are running away from Germany and are moving to Dubai? Is it a real alternative?

Khaled: The alternative is Middle East – let alone the money and the business possibilities. The future of business, especially the pipe industry, is here. In Saudi, we have the vision of our prince, which will be realized by 2030. Parallelly, we will host the football World Cup in 2034. You as a German will know, what needs to be prepared for that. Saudis take a lot of German companies for these projects, because they are aware of the quality. Also, we have done many things to attract more tourists and raise awareness of the beauty of Saudi. Alone in the Red Sea we have more than 24 islands, 11 of them ready with hotels, spas, and entertainments to welcome tourists and guests. Then there is Neom, one of the biggest projects in the world. Whatever the prince dreams, he makes it reality. Then we have Aquarabia in Qiddiya City, the world's largest aqua park, one hour away from Riyadh. That's only a bit of what is to come.

Alexander: So, all of the strict rules have changed? The country is now open for party amusement? Can I just bring a girl in a short dress to drink alcohol together at the beach for example? Six years ago it took me 6 months to get a visa – without a girl in a short dress with alcohol of course.

Khaled: First of all, it takes 10 minutes online for a visa application. Secondly, you can come with your family, girlfriend, anybody, they can wear whatever they want, but Alcohol is still prohibited. A lot of tourists come here now.

Alexander: So you say for us the main market would be in Middle East, what do you think about the production area of Europe, especially Germany? Now after Covid everything is different in Saudi, it's booming. What do you think about Germany, as I am a little bit sad about the location at the moment.

Khaled: You have to make an office in the Middle East. Saudi or Abu Dhabi or Dubai. You can open a company in 30 minutes. This will give you more opportunity to grab business here. The business in this area is huge. They companies here will not continue to look for business partners in Germany or Europe or the US. These companies come here, they all have an office here. Any big company. My advice is you make an office, bring your employees and we will meet again in 3 years and you will tell me, how your business has grown.

Alexander: The biggest market in the Middle East for you in Saudi. What do you think where we should concentrate on?

Khaled: I will give you a small example. Saudi housing and municipalities have placed a consulting contract by 600bn riyadhs to 6 consultants for sewage and stormwater. Also we do not forget water desalination plants, power plants, this is for the next 20 years. We are goind to be very busy with that,

Alexander: If I were to tell my employees or business partners in Germany that I want to open an office in Saudi, they would think it would mainly be for tax reasons. But your approach is a different one, you're saying that being close to my customer is what they want, and if we won't do it, somebody else will. We cannot wait any longer for them to find us or come to us in Germany, but we will have to come to them – the time of travelling is over. Is this correct?

Khaled: Very correct. I will give you one tip: Chinese have their offices here. They produce here and sell all the copies here. Also your machine. Of course the quality is on a whole other level, we do not need to talk about this – but they are here and present. All their equipment worth millions is here. They have bank accounts and employees here. Forget about the old stories. They will have to come, live here and take the world. There is nobody here who doesn't believe you have the best product. But you are slow. You still think the business is the same like 10 years ago – it isn't. And this is my advice.

Alexander: That gives me a lot to think. Thank you for being so open. In Europe, we live in a Work-Life-Balance mode, which is just in Europe I think. We have to change, I cannot wait anymore. Thank you so much for your time, Khaled.

Saudi Vision 2030

Saudi Vision 2030 is a strategic plan launched by Saudi Arabia to diversify its economy and reduce its dependence on oil. The initiative, introduced in 2016 by Crown Prince Mohammed bin Salman, aims to transform the country by focusing on key areas such as:

Economic diversification: *Expanding sectors like tourism, entertainment, renewable energy, and technology.*

Social reforms: *Empowering women, improving education, and enhancing quality of life.*

Government efficiency: *Increasing transparency, privatizing certain state-owned enterprises, and improving governance.*

Vision 2030 seeks to create a sustainable economy, modernize Saudi society, and position the country as a global economic and cultural hub by 2030.

Krah GmbH Sponsors Two Engineering Students in the Philippines

Krah GmbH, a global leader in large-diameter pipes and infrastructure solutions, has expanded its corporate social responsibility program by sponsoring two exceptional engineering students from the University of Santo Tomas (UST) in the Philippines. The scholars, Franchezka Louise Miranda and Cedrick Simbol, were chosen for their academic excellence and dedication to engineering. This partnership with the UST Engineering Alumni Association (USTEAAI) aims to nurture future leaders in the field.

Franchezka Miranda: Building with Purpose

Franchezka Miranda, a first-year civil engineering student, has demonstrated outstanding academic and extracurricular achievements. A graduate of Southern Luzon State University Laboratory School, she has long been passionate about engineering's role in creating and ensuring safety in society. "This scholarship has brought me closer to my dreams," she says, crediting Krah GmbH for enabling her to study at her dream university and inspiring her to one day join their innovative team. Franchezka aims to graduate with Latin Honors, pursue advanced studies, and provide for her family.

Cedrick Simbol: Passion for Service

Cedrick Simbol, a second-year civil engineering student, is driven by his Christian faith and a commitment to excellence. For him, engineering is a calling, combining passion and purpose. "The idea that sketches can turn into skyscrapers fascinates me," he shares. Cedrick views his scholarship as a privilege and a motivation to excel academically, honoring the faith of his benefactors. He aspires to pass the board exams and use his skills to contribute to society, fulfilling his belief that "to study and work is to serve."

This collaboration between Krah GmbH and USTEAAI underscores the company's dedication to fostering the next generation of engineers. By supporting Franchezka and Cedrick, Krah GmbH is investing in a future where innovation and service are at the heart of engineering excellence.

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Dr. Andreas Klippe, aka „Dr. Flood" on the Future of Flood Protection

An interview with Dr. Alexander Krah and Dr. Andreas Klippe, also known as „Dr. Flood," an internationally recognized expert in flood protection and water management.

Dr. Alexander Krah: Good morning, Andi! I'm very excited to talk to you today about flood protection. You're known as „Dr. Flood" and are considered an expert in managing extreme rainfall and water disasters. In your opinion, what is the biggest difference between flood events in Southeast Asia and here in Germany?

Dr. Andreas Klippe: Good morning, Alexander! There are indeed some significant differences. In Asia, temperatures are typically higher, so floods can occur at any time of the year. In Europe, on the other hand, we mainly experience floods during the winter months when it's cold and freezing. However, in Asia and the Middle East, the temperatures are constantly high—often between 30 and 40 degrees Celsius or even higher.

But regardless of the location, floods have the same consequences everywhere: destruction, massive damage to buildings and infrastructure, and people living in fear. In the end, such events destroy not just material values but also people's sense of security.

Dr. Krah: That sounds worrying. When I think back to my youth, I feel like there were more floods back then than there are today. Is my feeling deceiving me, or is that actually true?

Expert interview

Flooding catastrophy in Ahrtal, Germany in 2021

Dr. Klippe: Your feeling isn't entirely wrong. It might seem like we have fewer floods today, but in reality, we are dealing with more frequent and intense flood events now. I think this is a direct result of climate change. Even if you don't believe in climate change, it doesn't change the facts: it rains more, and the rainfall is more intense. The amount of water falling in a shorter period is much higher than it used to be. That's what matters—not whether you believe in climate change or not, but whether you are prepared to protect yourself and your environment from these dangers.

Dr. Krah: I completely agree. It doesn't matter whether climate change is man-made or not—we have to deal with the consequences. This includes unexpected heavy rainfall. I've heard that in the Middle East, they're using a technique called „Cloud Seeding." Can you explain what that is and how it works? Could it be dangerous?

Dr. Klippe: „Cloud Seeding" is actually an interesting technique that has been around for several years. Basically, silver iodide particles are shot into the clouds. These particles act as condensation nuclei, causing the water droplets in the clouds to accumulate faster and turn into rain. The idea is to control the amount of rain and concentrate it in specific areas. But nature isn't so easily controlled—rain can still fall where you don't want it because you can't control the wind. Countries like the United Arab Emirates are experimenting with this to improve water availability in their extremely dry regions.

Dr. Krah: That sounds like a risky endeavor. When I first heard of „Cloud Seeding," I thought it might even be possible to create clouds. But it's more about using existing clouds to influence the intensity of rainfall?

Dr. Klippe: Exactly, that's right. It's about influencing the growth of clouds so that it rains in specific areas and not where you want to avoid it. However, in big cities like Dubai, there's a big problem: there's a lot of concrete and not much natural landscape left. Additionally, they often lack adequate drainage systems to quickly divert water. This means that even small rainfalls can quickly lead to major flooding.

Dr. Krah: Another phenomenon I recently read about is called „Omega-3 weather." Can you explain what that's about?

Dr. Klippe: „Omega-3 weather" is a term from meteorology. It describes a weather pattern where two low-pressure areas and one high-pressure area position themselves in such a way that they together form the shape of the Greek letter Omega. This constellation often leads to stable weather patterns with a lot of precipitation in a confined area. Even though I'm not a meteorologist, I know as a flood protection engineer that such weather patterns can pose a significant danger.

Dr. Krah: And what about La Niña and El Niño? These terms often come up in connection with extreme weather events.

Dr. Klippe: La Niña and El Niño are climate phenomena that originate in the Pacific Ocean. The terms come from Spanish, meaning „the girl" (La Niña) and „the boy" (El Niño). They describe unusual changes in sea surface temperatures and air pressure conditions that can affect weather worldwide. For example, La Niña causes cooler temperatures in the Pacific and can lead to drier weather in South America, while El Niño is associated with warmer water temperatures and heavy rainfall. These phenomena can trigger global weather extremes, such as droughts, floods, and storms.

Dr. Krah: These are really complex connections! When we look at urban planning: how should cities be designed, in your opinion, to better handle flooding in the future?

Dr. Klippe: There are various strategies that cities can use to better prepare for floods. First, we need to install better drainage systems in urban areas—pipes that are large enough to quickly drain large amounts of water.

Second, we should build more underground water storage systems to capture excess rainwater. And third, we need modern flood protection barriers and individual protective measures to shield houses and critical infrastructure from flooding. It's about managing the flow of water and minimizing the impact of floods.

Dr. Krah: That sounds like a comprehensive approach. If someone wants to learn more about flood protection or seek your help, what's the best way to contact you?

Dr. Klippe: Interested parties can find me through my website www.andreasklippe.com. I'm happy to answer questions and provide advice. Flood protection is a challenge we all have to face, and I'm glad to help.

Dr. Krah: One last personal question: Do you believe we're on the right track when it comes to flood protection? Should we continue to invest so much energy and resources into this work?

Dr. Klippe: Absolutely. There are moments when it can be frustrating because we often feel like we're fighting an uphill battle. But we know our work is important. We must continue because natural disasters, especially floods, will continue to increase. People need us, and it is our responsibility to do everything we can to ensure their safety and well-being.

Dr. Krah: Thank you Andi, for this insightful conversation. It was a pleasure!

Flooding in Indonesia, 2022

Upscaling of pipe stiffness results acc. to ISO9 polyethylene pipes

1. Introduction

Structured wall pipes manufactured according to DIN EN13476[I] should be classified into SN classes (Stiffness Nominal) in accordance with ISO13966[II] . ISO9969[III] sets the rules & conditions for the actual testing. The larger the pipe diameter to be tested, the more difficult it is to find suitable laboratory equipment. Many pipe producers and even independent third-party laboratories have a limitation on the largest testable pipe.

This paper aims to prove that a semi-theoretical upscaling of the physical test-result regarding pipe stiffness can be used to prove that the stiffness of a larger diameter pipe can be tested on a smaller references diameter.
The SN-value has no relation to the actual needed stiffness according to site conditions.

2. Methodology

At the production plant, two pipes will be produced with the same machine setup and material, only the tool for the pipe diameter will be different.

In a first step, a theoretical SN-class is calculated based on the geometrical data of the wall structure. From each pipe, three test samples will be cut and prepared for lab-testing. Both pipes will be tested according to ISO9969. Prove that the equation will reach the same results as the physical testing.

3. Semi-theoretical approach

Basically, all physical tests will prove the bending stiffness - flexural rigidity (M) of the profile/structured wall depending on the used raw-material properties.

$$M = E_s * I_x \tag{1}$$

Based on the standard equation for calculating a SN-value

$$SN = \frac{M}{D_m^{\ 3}} \tag{2}$$

Where E_s is the short time e-modulus of the material [N/mm²], I_x the specific area moment of inertia [mm^4/mm], D_m the mean pipe diameter [mm], *SN* the nominal pipe stiffness [kN/m²] and *e* the distance of inertia of the structured wall [mm].

A new formular will be generated to scale up the stiffness test results from a reference diameter (D_{ref}) to another demanded diameter (D_D) by using the same "bending stiffness" (M) of the structured wall and the result of a practical stiffness test (SN_{Ref}) for a pipe with the reference diameter (D_{Ref}).

$$SN_D = SN_{Ref}\left(\frac{D_{ref}}{D_D}\right)^3 \tag{3}$$

Equation 3 is the basis to upscaling the SN value from one diameter to another.

4. Practical proof

Two different pipe diameters were produced (production date: 3rd of August 2024) with the same machine (KR900) and the same material specification and the same wall structure. One pipe with an DN/ID1500 and another with DN/ID2000.

The products were produced in Estonia at Krah Pipes OÜ. Krah Pipes OÜ has a stiffness testing machine[iv] to perform constant speed stiffness tests according to ISO9969, with a maximum testing range of DN/OD65 – DN/OD2340. The stiffness test was made on the 8th of August 2024.

The same wall structure (Type: OP) was produced on a pipe with an internal diameter of DN/ID1500 and DN/ID2000.

a) Profile shape

The produced structure wall pipe is made of PE100 material[v]. Short term E-modulus is 1080 [N/mm²][vi] , the profile dimensions are theoretical and real:

969 for large, structured wall

	Theoretical / geometrical ap-proach	DN/ID1500mm	DN/ID2000mm	Remark
S1 [mm] waterway	7	7,67	7,03	Over
S4 [mm] Coating	6	6,8 (4,81-8,93)	7,18 (5,71-8,96)	Over
A [mm]	120	116	113,8	Under
H [mm]	145,61	137,1	135	Under
E [mm]	60,48	56,18	56,66	Under

Table 1: Profile dimensions (mean values – in brackets is the bandwidth)

	Theoretical weight [kg/m]	Real weight [kg/m]
DN/ID1500mm	191,59	193,00
DN/ID2000mm	250,70	256,00

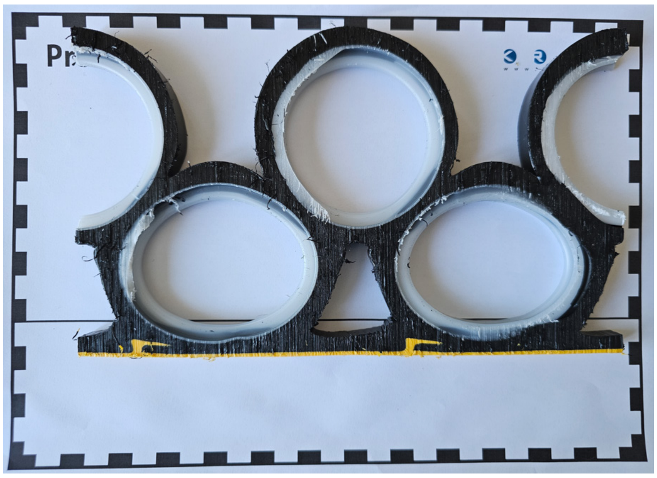
Table 2: Pipe weight

	Theoretical stiffness [kN//m²]
DN/ID1500mm	7,82
DN/ID2000mm	17,52

Table 3: Pipe nominal stiffness, according to MICKEY[vii]

The used core-tube in both pipes is from the same batch. The real pipe geometry varies slightly from pipe to pipe resulting from the specifics of the production process. The dimensions achieved on both test pipes are comparable with each other, thus fit for the purpose of this proof.

The mean distance of inertia is (e) = 56,4 [mm]. The distance of inertia was determined using a software ProJen based on a graphical analysis[viii].



Sketch 1: Sketch of the used wall structure

We consider a lower stiffness because the height of the structured wall is lower than in the theoretical approach.

- The pipe DN/ID 1500 is 0,7% heavier than the theoretical approach.
- The pipe DN/ID 2000 is 2,1% heavier than the theoretical approach.

b) Test results for DN/ID1500mm

The produced pipe DN/ID 1500 with the profile type OP75-067.83 was cut in three different test specimens. The preload was set to 375 N and the test speed was 45 mm/min.

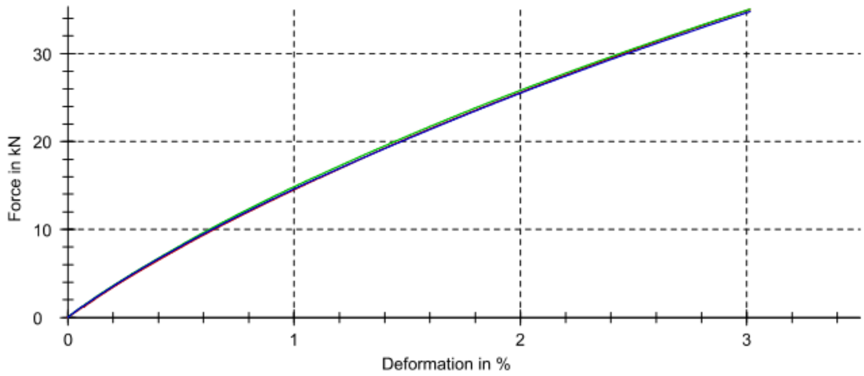


Diagram 1: Showing the force in [kN] in relation to the deflection [%]

Leg-ends	Speci-men	Spec-imen Side	F kN	$S_{a,b,c}$ kN/m²	S kN/m²	$d_{ia,ib,ic}$	d_i m	y/d_i %	L m	d_n mm	e_c mm	P mm	M kg/m
(red)	1	a	34,9	14,928	14,90	1,503	1,504	3,0	1,002	1778,6	137,1	116,3	193
(green)		b	34,9	14,941		1,506		3,0	1,002	1778,6	137,1		
(blue)		c	34,6	14,821		1,504		3,0	1,002	1778,6	137,1		

Table 4: Test results

Series n=3	F kN	$S_{a,b,c}$ kN/m²	S kN/m²	$d_{ia,ib,ic}$	d_i m	y/d_i %	L m	d_n mm	e_c mm	P mm	M kg/m
x	34,8	14,897	14,90	1,504	1,504	3,0	1,002	1778,6	137,1	116,3	193
s	0,154	0,066	-	0,002	-	0,0	0,000	0,0	0,000	-	-
v	0,44	0,44	-	0,10	-	0,00	0,00	0,00	0,00	-	-

Table 5: Statistical results

The test result for the pipe size (D_{Ref}) DN/ID 1500 was SN_{Ref} = 14,90 kN/m².

c) Test results for DN/ID2000

The DN/ID 2000 pipe produced with profile type OP75-067.83 was cut in three different test specimens. The preload was set to 500 N and the test speed was 60 mm/min.

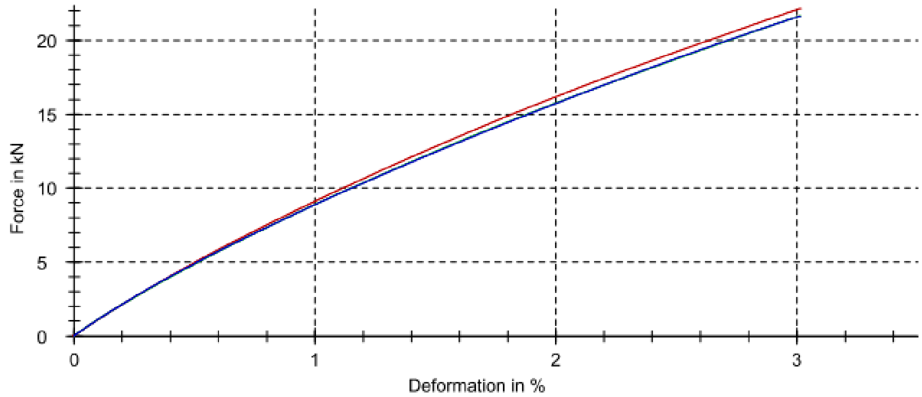


Diagram 2: Showing the force [kN] in relation to the deflection [%]

Leg-ends	Speci-men	Spec-imen Side	F kN	$S_{a,b,c}$ kN/m²	S kN/m²	$d_{ia,ib,ic}$	d_i m	y/d_i %	L m	d_n mm	e_c mm	P mm	M kg/m
(red)	1	a	22,1	7,118	7,01	2,005	2,002	3,0	0,999	2271,9	135	113,8	256
(green)		b	21,6	6,957		1,999		3,0	0,999	2271,9	135		
(blue)		c	21,6	6,956		2,002		3,0	0,999	2271,9	135		

Table 6: Test results

Series n=3	F kN	$S_{a,b,c}$ kN/m²	S kN/m²	$d_{ia,ib,ic}$	d_i m	y/d_i %	L m	d_n mm	e_c mm	P mm	M kg/m
x	21,7	7,010	7,01	2,002	2,002	3,0	0,999	2271,9	135	113,8	256
s	0,289	0,093	-	0,003	-	0,0	0,000	0,0	0,000	-	-
v	1,33	1,33	-	0,15	-	0,00	0,00	0,00	0,00	-	-

Table 7: Statistical results

The test result for the pipe size (DD) DN/ID 2000 was SNRef = 7,01 kN/m².

d) Semi-theoretical approach

Upscaling the test result according to equation 3 with the following values.

D_{Ref} = 1500 [mm] + 2 * 56,4 [mm] = 1.612,73 [mm]
SN_{Ref} = 14,90 kN/m²

D_D = 2000 [mm] + 2 * 56,4 [mm] = 2.112,73 [mm]

$$SN_D = 14,90\ \left(\frac{1.612,73}{2.112,73}\right) = 6,62734 \qquad (4)$$

The nominal stiffness for the required diameter (DN/ID2000) is 6,63 [kN/m²], based on the semi-theoretical approach (the real stiffness is 5,774 % higher).

e) Reverse-calculation

As a short (untypical) calculation, the results and values for the pipe DN/ID2000 are used to get the semi-theoretical results for DN/ID1500.

D_{Ref} = 2.112,73 [mm]
D_D = 1.612,73 [mm]
SN_{Ref} = 7,01 [kN/m²]
SN_D = 15,75 [kN/m²]
(The real stiffness is 5,774 % lower)

f) Result:

The approach was that using the semi-theoretical equation to upscale the stiffness would lead to a conservative result:

- DN/ID 1500 = SN 14,90 kN/m² (tested)
- DN/ID 2000, SN = 7,01 kN/m² (tested)
- DN/ID 2000, SN = 6,65 kN/m² (upscaled, based on DN/ID1500 test result)

5. Limitation

More test specimen and different pipe structures should be tested. It is important to check whether there is a maximum relationship between the diameters. The production technology is not able to produce in those low tolerances to avoid different results. It is impossible to guarantee exactly same parameters on two different pipes, thus generating some variability on proofs like this.

6. Conclusion

The theoretical approach of this work was confirmed by practical testing. The theoretical approach is more conservative and will give a certain margin of safety. The purpose of this work was to show that it is possible to reliably estimate the stiffness of larger diameter pipe, by using a semi-theoretical approach. This approach is combining real laboratory testing of smaller diameter pipe and upscaling the real test result to the intended larger diameter pipe with the same profile. It was proven that the proposed semi-theoretical approach is conservative and yields lower stiffness of the larger pipe, than the actual testing revealed the stiffness to be, thus providing a certain safety margin by using such approach.

There are several practical implicatios of the described procedures. First, producers and third party independent laboratories can use their existing equipment to certify larger range of pipe diameters, thus eliminating the need for large investments into bigger machines. Verification and certification procedures will be simpler and faster as there are more third party independent laboratories available. Another benefit is that specific profile requirements for large diameter pipes can be verified without timeloss using existing labortories at producer's facilities, thus making quality verifications easier for the customers. Overall, this is a very sustainable approach, as larger pipes no longer need to be transported.

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[i] *DIN standard for plastics piping system for non-pressure underground drainage and sewerage – structured-wall piping systems*

[ii] *DIN standard for thermoplastics pipes and fittings - nominal ring stiffnesses*

[iii] *DIN standard for thermoplastics pipes - determination of ring stiffness*

[iv] *Type: Zwick-Roell BS1-FR100TEW.A2K.008 (serial number 190232/2009)*

[v] *Borealis BorSafe HE3490-LS in bags*

[vi] *Borealis Certificate*

[vii] *Mickey is a Software provided by the manufacturer.*

[viii] *was calculated by the Steiner Theorem*

Short news

The new **BIG & BEAUTIFUL** wall calendar for the year 2025 is now available. If you haven't already received your copy, make sure to contact us at marketing@krah.net and we'll send you some copies. A big "Thank you" to Frank GmbH in Germany who yet again provided us with a perfect shooting location, making this calendar a really special one. Also, some shots were done in the Pilippines in a very interesting construction site location, it's definitely worth taking a look.....

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