CASE STUDY ON REHABILITATION INSTALLATIONS WITH A NEW TAILOR MADE PP-RCT PIPE SOLUTION

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ABSTRACT

Keywords: Coes, Borealis, PP-RCT, Beta PPR, Hexa, Coestherm, Multilayer, Plumbing

The use of Polypropylene Random-Copolymers (PP-R) in the domestic plumbing and heating systems has shown since its first applications more than 20 years ago, that this kind of polymers fit excellent to the demand on pressure resistance at elevated temperatures, combined with good durability. A continuous and respectable growth over these years with an immaculate image has been achieved.
By looking forward for additional options to match customer requirements a new material class PP-RCT (Lit.1) has been developed for this application field. In the herein presented case study the implementation of this material into a new innovative 3-layer piping system, the COESTHERM HEXA MULTILAYER PIPE, will be described.
The pipe combines the benefits of the improved pressure resistance and long term durability of the PP-RCT (Boralis Beta PP-R) at elevated temperatures. This solution offers new possibilities to planners, installers and end-users in different aspects, like higher hydraulic capacities or higher permissible operating pressures to cover the hot&cold water distribution over more floors, or faster installation through the chance to down-gauge the dimension of pipes.
Beside these benefits the paper describes a practical example of a project carried out with this PP-RCT pipe system.

INTRODUCTION

Even if PP-R piping systems are already available since more than 20 years there were once other materials applied, which are needed to be replaced with increasing number. Many times these old pipes show excessive corrosion, deposits with close to zero (0) transport, or leakages caused by threaded connections. When finally rehabilitation will be tackled the room for working are often underestimated.

The problems of the rehabilitation of the Nile Hilton hotel, in Cairo were in this case the starting point to develop this new Hexa pipe, a multilayer pipe of different grades of Polypropylene: PP-RCT & PP-R.

Fig. 1 Nile Hilton Hotel , picture from website

Fitting a plastic pipe in an existing building can be a problem because plastic pipes are usually bigger than metallic pipes to be replaced, so reducing the wall thickness keeping the pressure level can be very important in this case. A similar problem must be solved for big cruise ships whenever metallic pipes are replaced to eliminate corrosion.

CHAPTER 1. FINITE ELEMENT INVESTIGATION

Before starting to analyse a FEM model of a pressurized pipe, please find an intermediate step of the consideration, which was a hoop stress calculated for a PPR pipe DN 75, SDR 7,4.

Table 1) PPR

External diameter (mm)	Wall thickness (mm)	SDR	Series	Working pressure (bar)	stress (MPA)	stress limit(*) @ 70° for 50years	Safety margin
75	10,3	7,4	3,2	10	3,2	3,2	1,00(**)

Table 2) PP RCT

External diameter (mm)	Wall thickness (mm)	SDR	Series	Working pressure (bar)	stress (MPA)	stress limit(*) @ 70° for 50years	Safety margin
75	10,3	7,4	3,2	10	3,2	5,1	1,59

(*) According to DIN standard 8078-2008-09

(**) The typically applied minimum safety factor of C-min =1,5 is not given. In this case it is necessary to change the SDR from 7,4 to 6, which is corresponding to an increase of the thickness from 10,3mm to 12,5mm (+ 20%).

1.1 Multilayer pipe: model description:

Geometry:

- external diameter: 75 mm
- thickness: 10.2 mm

FE model:

- Mesh is already designed for a multilayer pipes, properties of layers are identical
- element type: 4 nodes plane strain element (Fig.4)
- large strains and large displacements option

Material: PPR,

- Elastic modulus: 900 MPa
- Poisson coefficient: 0.42
- Yield limit: 25 MPa
- Thermal expansion: 0.00015 K^{-1}
- Constitutive law: perfectly elasto-plastic material (Fig.2)

Boundary conditions:

- temperature field: 70°C
- internal pressure: 1 MPa (10bar)
- double symmetry constraints (Fig.5)

Time history of the load case:

- see diagram in the picture Fig. 3

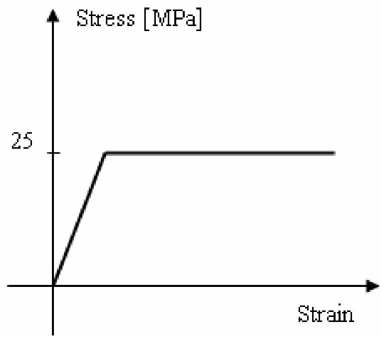

Fig.2: elasto-plastic law

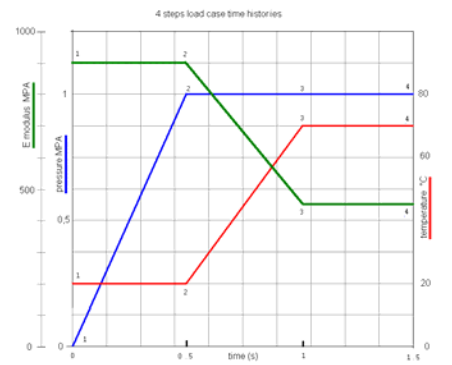

Fig.3: Time histories

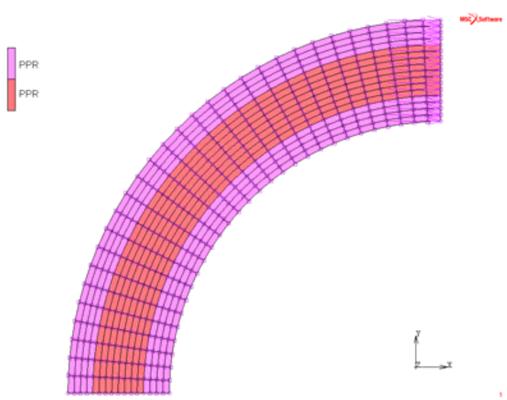

Fig.4 Mesh

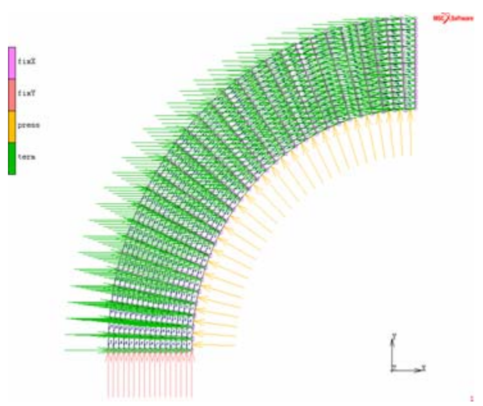
Fig.5 Boundary conditions

1.2 Results

This mathematical model is valid for both PPR and PP RCT because the static parameters are equivalent. The stress distribution can be seen in the pictures Fig. 6 & 7.
Yellow, red and blue define 3 levels of stress in the wall thickness.

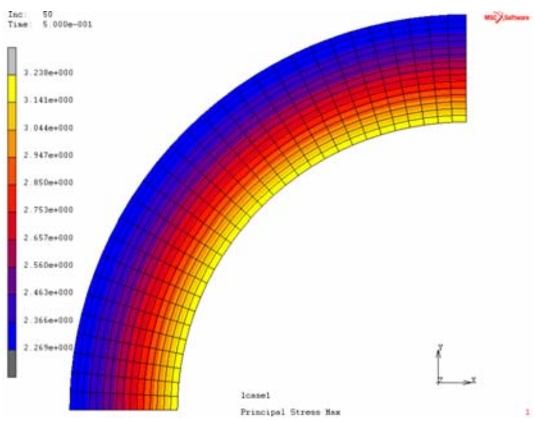

Fig.6 Stress @ Pressure 1 MPa, T= 20°C

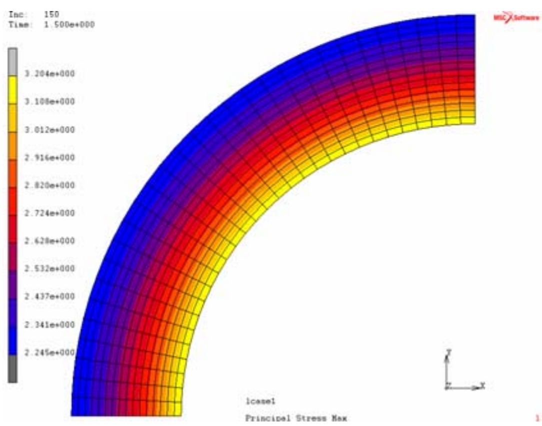

Fig. 7 Stress @ Pressure 1 MPa, T= 70°C

Based on these results from the FEM a 3-layer pipe was considered for further calculations. In the tables 3 and 4 the results from this assumption are presented. In detail it shows that, as expected, the secured stress levels of PP-R are exceeded, whereas the PP-RCT shows a respectable safety margin in all layers.

Table 3) PPR

Layer	stress level @ room temperature	stress level @ 70°C	stress limit(*) @ 70° for 50years	Safety margin @ 70°C	Note
internal	3,3	3,2	3,2	1	too low C-min.
intermediate	2,8	2,7	3,2	1,2	too low C-min.
external	2,4	2,3	3,2	1,5	Ok

Table 4) PP RCT

Layer	stress level @ room temperature	stress level @ 70°C	stress limit(*) @ 70° for 50years	Safety margin @ 70°C	Note
internal	3,3	3,2	5,1	1,6	Ok
intermediate	2,8	2,7	5,1	1,9	Ok
external	2,4	2,3	5,1	2,2	Ok

A multilayer solution is the logical conclusion of this analysis, thus optimizing the material resistance. Many other practical advantages can be diverted, which are described in chapters 2 and 3. Immediately it should be pointed out, that the most important advantage is the "predictable long term life" based on existing and certified regression curves. (Lit.2)

Table 5) Multilayer pipe PP-RCT / PPR

Layer	stress level @ room temperature	stress level @ 70°C	stress limit(*) @ 70° for 50years	Safety margin @ 70°C	Note
internal	3,3	3,2	5,1	1,6	Ok
intermediate	2,8	2,7	5,1	1,9	Ok
external	2,4	2,3	3,2	1,5	Ok

A multilayer pipe with a composite intermediate layer was also studied, but this solution could not fit our case because of the long time necessary to qualify the long term resistance of the compound.

CHAPTER 2. LONG TERM LIFE OF A MULTILAYER PIPE.

Technical specification ISO 17456 "Plastics piping systems - Multilayer pipes - determination of long-term strength" (Lit 3) gives a criteria to predict the long term life of a multilayer pipe when the regression curves of the material of each layer are available and certified. The criteria are expressed in the following formula in Fig.8.

$$p_{T,t} = 20\sum_{1}^{n}\frac{e_n\sigma_n}{d_n - e_n}$$

Fig. 8 Calculation formula for the validation of the pressure strength

Legend:

E_n is the wall thickness of each layer (mm),

n is the number of layers

D_n is the outside diameter of each layer (mm),

σ_n is the hoop stress in MPA of the material of each layer measured @ temperature **T** and for the time **t**,

$P_{T,t}$ is the calculated pressure @ the temperature **T** and for the time **t** for the **n**-layer pipe expressed in bar.

This formula has been derived directly from the hydrostatic stress equation (Lit.4).
According to this formula the following regression curves (Fig 9) can be calculated, starting from data set of each material. (Lit.5+6)

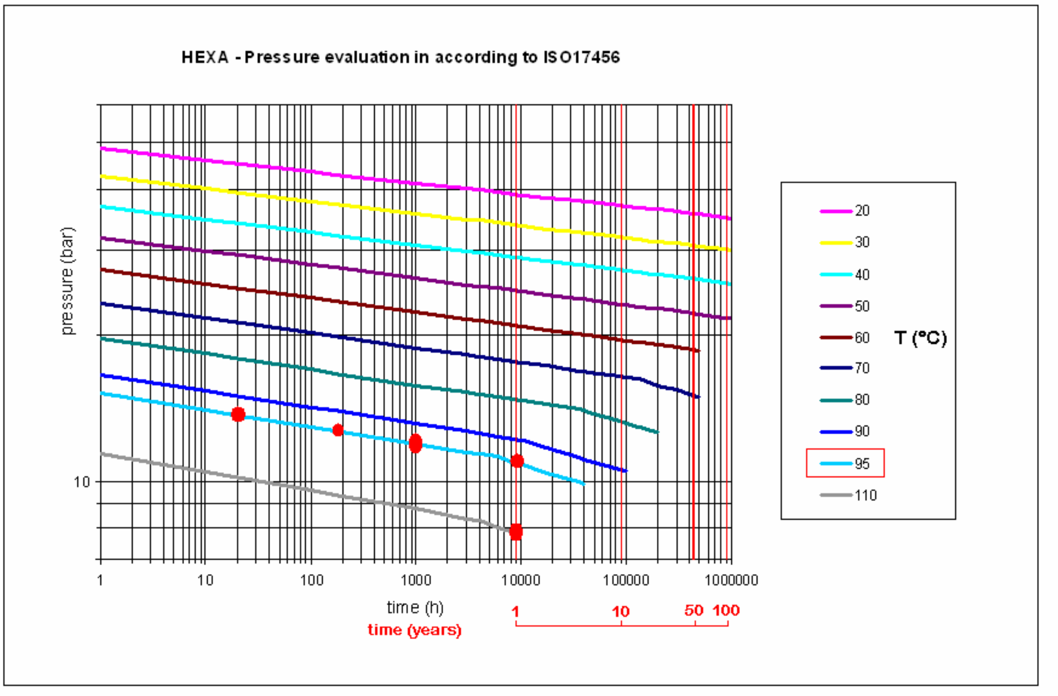

Fig. 9 pressure regression curve for the Hexa pipe

The "Red" points therein describe the control points tested to validate the Hexa Pipe: (four points @ 95°C, 1 point @ 110°C).

CHAPTER 3. BENEFITS OF A MULTYLAYER SOLUTION.

The first improvement of this development by using the PP-RCT is the wall thickness reduction of about 20% (table 1 and table 5).
This reduction potential can be implemented by reducing the wall thickness from SDR 6 to SDR 7.4, which increases the internal diameter and as consequence the water flow. But it allows as well a down-gauging of the pipe in comparison to conventional PP-R piping systems, while supplying the hydraulic capacity as required. Both alternatives reduce at the weight of the pipe.

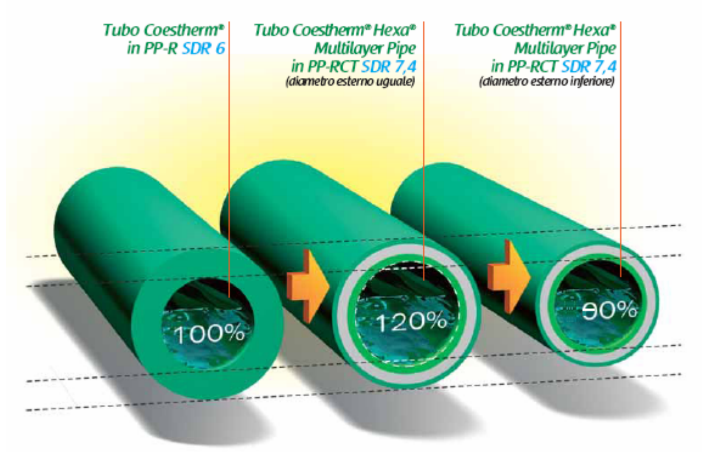

Fig. 10 comparison of a PPR pipe with the PPRCT multilayer solution

With this exercise of theoretical calculation and empirical tests it is demonstrated how a multilayer pipe can optimize stress distribution and can guarantee long term durability. Another advantage of this solution is the low temperature resiliency because no filler has been used. The low temperature resistance is the same for PP-R and PP-RCT, therefore it is the same for a multilayer pipe combining the 2 materials. Fig.11.

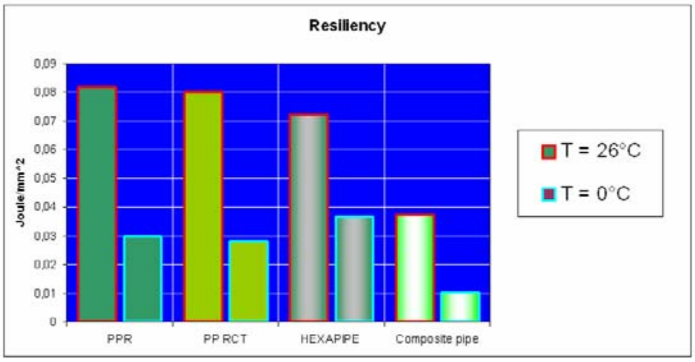

Fig.11 Impact resistance tested on pipes

The colour change from layer to layer is another improvement. It is helpful in production to keep layer thickness under control.
External layer can be changed for aesthetic or on marketing purpose. For the herein presented Hexa pipe the same colour as common to all the COES PPR fittings has been applied. Combining Hexa pipe with any fitting will result in a uniform installation. It is not necessary to produce and to stock specific fittings.
Optionally this multilayer pipe solution offers further potential, as for instance the internal layer can be optimized to improve the chemical resistance.

In respect to the jointing of the pipes the usual polyfusion (socket welding) is applied without any limitations, wherefore fittings identical to standard COES PPR pipe are recommended. As alternative welding method the butt fusion can be done as well with no restrictions, which becomes relevant especially for bigger dimensions where no socket fusion fittings are available anymore.

CONCLUSION

With the new improved class of PP-R, the Borealis Beta-PPR RA7050 (classified as PP-RCT) and a sophisticated calculation methodology were the keys to match customer’s requirements of water flow and pressure resistance. The developments of this effective and reliable solution for hot and cold water piping system took a reasonable short time and allow designers and plumbers to take full advantage in engineering and installing it.

Literature Reference:

Lit.1: DIN 8078:2008-09, “Polypropylene pipes – PP-H, PP-B, PP-RCT – General quality requirements and testing”

Lit 2: PPXIII 2006, “PP-RCT – A new material class for plumbing and heating applications”, by R. Gard

Lit.3: ISO 17456 “Plastics Piping Systems – Multilayer Pipes – Determination of Long Term Strength”

Lit. 4: EN ISO 15874-1 “Plastics piping systems for hot and cold water installations – Polypropylene (PP) – Part 1: General”

Lit. 5: Regression analyses in accordance to ISO 9080 of the PP-R pipe grade RA130E by Bodycote/Borealis

Lit. 6: Regression analyses in accordance to ISO 9080 of the PP-RCT pipe grade Beta-PPR RA7050, by Bodycote/Borealis