New opportunities in erosion control, waterproofing and slope protection.

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ABSTRACT: In 2010 an innovative technology was introduced in Spain and has been successfully used on a variety of Maintenance applications as well as building and civil engineering works: Manta de Hormigón (Concrete Canvas™). It´s a flexible fabric that hardens on hydration to form a thin, durable, concrete layer. It consists on a tridimensional fiber matrix contained special formulated dry cement. Crawford & Brewin (2010) The PVC backing on one surface ensures that the material is completely waterproof. Manta de Hormigón is extremely easy to use. There is no need for mixing or measuring, nor compacting is required: Just add water. It enables the rapid installation of concrete structures across a broad range of applications "Manta de Hormigón" has already been tested and successfully used at many constructions sites. New uses are being planned and are due to be trialed shortly. Many applications are currently in the research and development phase and many others are still to be investigated.

1 DESCRIPTION OF THE MATERIAL.

1.1 *What is it*

Manta de Hormigón (MdH) (Concrete Canvas™) is a flexible fabric that hardens on hydration to form a thin, durable, concrete layer. MdH allows concrete construction without the need for plant or mixing equipment. Simply position MdH and just add water. MdH consists of a tridimensional fibre matrix containing a specially formulated dry concrete mix. The material can be hydrated either by spraying or by being fully immersed in water. Once set, the fibres reinforce the concrete, preventing crack propagation and providing a safe plastic failure mode. The PVC backing on one surface ensures that the material is completely waterproof.

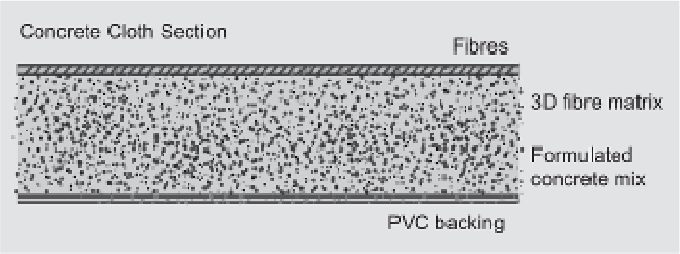

Figure 1. MdH section.

MdH is available in 3 thicknesses: CC5, CC8 and CC13, which are 5, 8 and 13mm thick respectively.

2 MDH KEY FACTS

2.1 *Easy to use*

MdH can be provided in bulk rolls, where lifting equipment is available, or in man portable rolls for applications with limited access or where heavy plant equipment is not available. There is no need for mixing or measuring, the concrete is premixed and cannot be over hydrated. It will set underwater even in sea water.

Figure 2. Man portable rolls.

Figure 3. Bulk rolls.

2.2 *Rapid*

Once hydrated MdH remains workable for 2 hours and hardens to 80% strength within 24 hours. Accelerated or retarded formulations can be produced to meet specific customer requirements.

2.3 *Environmentally friendly*

MdH is a low mass, low carbon technology which uses up to 95% less material than conventional concrete for many applications. It has minimal impact on the local ecology due to its limited alkaline reserve and very low wash rate. The impact on the environment is further decreased by reducing the need for plant equipment and machinery at building sites.

2.4 *Flexible*

MdH has good drape characteristics allowing it to take up the shape of complex surfaces including those with a double curvature. MdH can be cut or tailored using basic hands tool.

2.5 *Strong*

The fibre reinforcement prevents cracking, absorbs energy from impacts and provides a stable failure mode.

2.6 *Durable*

MdH is chemically resistant, has good weathering performance and will not degrade in UV.

2.7 *Water Proof*

The PVC banking on one surface of the MdH ensures that the material is completely water proof and chemically resistant.

2.8 *Fire resistant*

MdH is fire-safe, does not contribute to the surface spread of flames, has a low level of smoke development and minimal hazardous gas emissions. MdH has achieved Euroclass classification B-s1, d0.

2.9 *Low maintenance costs.*

Besides the aspects listed above, MdH is difficult to take away once set. The use of MdH has the advantage of lower maintenance costs than other solutions.

2.10 *Smooth and regular surface.*

This is an important aesthetic value to be taken into account in urban environment and a remarkable feature for hydraulic lines.

3 APPLICATIONS OVERVIEW

3.1 *Ditch Lining*

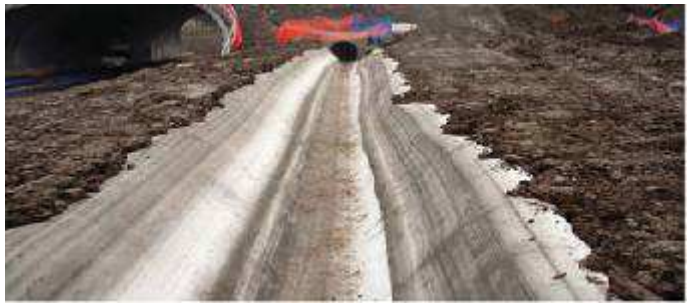

Figure 4. Ditch lining.

MdH can be rapidly unrolled to form ditch or channel lining. It is significantly quicker and less expensive to install than conventional concrete ditch lining and requires no specialist plant equipment. The 30m ditch shown above was lined in 45 minutes.

3.2 *Slope Protection*

Figure 5. Slope protection.

MdH can be used as slope stabilization and other erosion control applications such as temporary and permanent slope protection, retaining walls, boulder fences, low level bunds and river bank and dam revetments.

3.3 *Bund Lining*

Figure 6. Bund lining.

Secondary containment bunds can be quickly lined with CC to provide an efficient, chemically resistant alternative to concrete walling.

3.4 *Cable Protecting Covering*

Figure 7. Cable protective lining.

MdH can be installed in-line with existing cable laying equipment to provide protection against impact damage at a rate of 1000m/day. 200mm wide CC13 has been tested to BS 2484:1985
Impact Resistance for Straight concrete and clayware cable covers.

3.5 *Pipeline Protection*

Figure 8. Pipeline protection.

MdH can be used as a coating for overland or underwater pipeline protection, providing a superior tough rock shield. In remote areas it can be used to coat steel pipe on site without expensive wet concrete application plants. MdH will set underwater and provide negative buoyancy. CC13 meets the requirements of ASTM G13.

3.6 *Mining Application*

Figure 9. Mining application.

MdH can be used as an alternative to poured or sprayed concrete or as a quick way of erecting strong permanent or temporary blast and vent structures and spall lining.

3.7 *Ground Resurfacing*

Figure 10. Ground resurfacing.

MdH can be secured with ground anchors to rapidly create a concrete surface for flooring, pedestrian walk-ways or dust suppression. CC8 and CC13 have been tested to EN 1991-1-1:2002 (Resistance to Imposed Loads on Vehicle Traffic Areas)

3.8 *Other Applications*

Other applications include use as a general replacement for Shotcrete, retaining walls, scour protection, culverts, blinding layers, weed inhibiting, basement lining, water tanks, flood defenses, tunnel lining, architectural and design applications...

4 TECHNICAL INFORMATION

4.1 *Physical Properties*

Table 1. MdH dimensions

	Thickness (mm)	Size (m^2) Batch Roll	Size (m^2) Bulk Roll	With (m)
CC5	5	10	200	1.0
CC8	8	5	125	1.1
CC13	13	N/A	80	1.1

Table 2. MdH density

	Mass (unset) (kg/m^2)	Density (unset) (kg/m^3)	Density (set) (kg/m^3)
CC5	7.0	1500	+30-35%
CC8	12.0	1500	+30-35%
CC13	19.0	1500	+30-35%

4.2 *Setting*

4.2.1 *Working Time*

1-2 hours subject to ambient temperature MdH will achieve 80% strength at 24 hours after hydration.

4.3 *Method of Hydration*

Spray the fibre surface with water until it feels wet to touch for several minutes after spraying. Re-spray the MdH again after 1 hour if:

Installing CC5
Installing MdH on a steep or vertical surface
Installing in warm climates

MdH cannot be over hydrated and an excess of water is always recommended.
Minimum ratio of water: MdH is 1:2 by weight.
Do not jet high pressure water directly onto the MdH as this may wash a channel in the material.
MdH can be hydrated using saline water.
MdH will hydrate and set underwater.
MdH has a working time of 1-2 hours after hydration. Do not move MdH once it has begun to set.
Working time will be reduced in hot climates.
MdH will set hard in 24 hours but will continue to gain strength for years.
If CC is not fully saturated, the set may be delayed and strength reduced. If the set is delayed, re-wet with a large excess of water.

4.4 *Reaction to Fire*

CC has achieved Euroclass B certification:
BS EN 13501-1:2007+A1:2009 B-s1, d0

4.5 *Strength*

Very high early strength is a fundamental characteristic of CC. Typical strengths and physical characteristics are as follows:

4.5.1 *Compressive tests based on ASTM C473 – 07*

10 day compressive failure stress: 40 Mpa
10 day compressive Youngs modulus 150 MPa

4.5.2 *Bending tests based on BS EN 12467:2004*

10 day bending failure stress: 3.4 Mpa
10 day bending Young modulus 180 Mpa

4.5.3 *Tensile data*

Table 3. Tensile strength (kN/m)

	Length direction (kN/m)	Width direction (kN/m)
CC5	6.7	3.8
CC8	8.6	6.6
CC13	19.5	12.8

4.5.4 *Abrasion Resistance (DIN 52108)*

Similar to twice that of OPC Max 0.10 gm/cm^2

4.5.5 *MOHS hardness* *4-5*

4.5.6 *CBR Puncture Resistance*

EN ISO 12236: 2007 (CC8 & CC13 only)
Min. Push-through force 2.69kN
Max. Deflection at Peak 38mm

4.5.7 *Resistance to Imposed Loads on Vehicle Traffi c Areas*

EN 1991-1-1:2002 (CC8 & CC13 only)
Category G compliant
Gross weight of 2 axle vehicle 30 to 160kN
Uniformly distributed load not exceeding $5kN/m^2$

4.5.8 *Standard Test Method for Impact Resistance of Pipeline Coatings*

ASTM G13 (CC13 only) Passed

4.6 *Other*

4.6.1 *Freeze-thaw testing (BS EN 12467:2004 part 5.5.2) Passed*

4.6.2 *Soak-Dry testing (BS EN 12467:2004 part 5.5.5) Passed*

4.6.3 *Water impermeability (BS EN 12467:2004 part 5.4.4) Passed*

4.6.4 *Moisture vapour transmission rate*

PVC Thickness 0.42 mm
PVC MVTR range 0.836 - 0.924 g.mm / (m^2.day)
MdH Static Head <3.000 mm

The typical PVC thickness is 0.42 mm, therefore all values are related to it. Different PVC are available (ask for further information)

5 APPLICATION CASE STUDIES

5.1 *Slope protection, stabilization and waterproofing*

MdH can be used as slope stabilization and other erosion control applications such a temporary and permanent slope protection retaining walls, boulder fences, low level bunds and river bank and dam revetments. MdH is also useful in combating other elements which cause slope degradation such as rabbit´s burrows.
Herein we present some application case studies carried out on slopes.

5.1.1 *Alcobendas Tunnel entrance. Madrid. Spain*

Figure 11. Running jobs as the trains were passing.

In December 2010, ADIF, the Spanish authority responsible for railway infrastructure management, specified MdH to be used as slope protection for a tunnel entrance in a local rail line.
Erosion of the steep railway slope trenches had caused silting at the drainage pumps in the tunnel entrance. Shotcrete has long been the traditional solution, but presents several problems with installation and durability. These slopes had already been shotcreted twice and the durability of the solution was not satisfactory. In fact, gunite burst due to the ground water and had almost disappeared.
In this case, CC8 was specified and 2500 m^2 were delivered on site on bulk rolls. A small truck-crane was used for unloading and unrolling operations
The laying of MdH took place during the end of December and the beginning of January.
MdH was fixed on the top of slope by galvanized steel pegs. Steel screws were used to attach MdH adjacent layers. It enabled ground water free flowing and prevents water pressures. Besides, the continuous surfacing from the ditch lining in the top to the toe of slope helps to keep water away from the slope.
Despite the constraints because of both sunshine duration and low winter temperatures, installation rates over 450 m^2/day were reached.
The project was completed in under 7 days and was 70% quicker to install than traditional gunite.
The train traffic was not affected.
It should be noted that there are no discharge of material on the track during the laying of MdH, thus preventing interferences over the track traffic.

Figure 12. Construction equipment used. Slope height 12 m.

Figure 13. Steel screws were used to attach adjacent layers.

Figure 14. Continuous surfacing from the ditch lining in the top to the toe of slope.


Figure 15. MdH hydration by water spread.


Figure 16. Appearance of the gunita next to MdH. The gunite burst due to the ground water.

5.1.2 *Undermined slope by rabbit burrows in a railway line in Parla. Madrid.*

In 2011, ADIF entrusted the repair and protection of a cutting on the C4 suburbain rail line to TRAGSA. Slopes were being undermined by rabbit burrows. This situation was been accentuated by the rain water infiltration which was causing materials dragged downstream.

600 m^2 of CC 5 were specified. Work duration was a mere one day.The train traffic was not affected.


Figure 17. Slope appearance after being repaired.

5.1.3 *Coastal protection: Protection from landslide regression.*

In 2008 Rother council commissioned a major coastal protection project at Fairlight Cove on the south coast of England. The area has suffered from extreme landslide regression resulting in the loss of residential property and further threatening a large number of dwellings.

CC5 was specified by Rother Council´s geotechnical consultants to stabilize and protect a subvertical failure surface close to a key drainage facility. The steep nature of the slope prevented conventional slope stabilization techniques such as vegetation growth. MdH was supplied in areas with restricted access and where conventional concreting would be impossible.


Figure 18. Slope appearance.

5.2 *Channel waterproofing.*

5.2.1 *Tajo-Segura transfer repair.*

The Tajo-Segura transfer is a concrete channel, which in order to avoid leakage was waterproofed by laying a high density polyethylene membrane which was being separated from concrete due to wind. In order to avoid the lifting, a new cement mortar layer was added. Water ingress under the mortar had then caused the mortar to crack.

To solve this issue the mortar was removed and some new joints were created. These joints were protected by hypalon strips. The Confederación Hidrográfica del Tajo specified MdH CC5 to cover the strips in order to protect them from the erosion caused by solid material carried in water.

Figure 19. Placement of MdH on the joint.

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Figure 20. Appearance of the join repaired

5.2.2 *Monegros Channel.*

The Monegros Channel is an old concrete channel. Its cross section is 40 meters long.

To resolve the water leakage, the Confederación Hidráulica del Ebro specified CC5 as a waterproofing material.

Figure 21. Join appearance before repaired

CC5 was layed over the perimeter to water proof the channel surface.

-MdH was joined and sealed by overlapping layers and applying the automatic thermal welding procedure along the joint.

In this case, CC5 was specified and 1000 m2 was delivered on site in bulk rolls. A small truck-crane was used for unloading and unrolling operations.

Figure 22. Channel appearance during the repair works.

Figure 23. Tajo-Segura transfer once repaired.

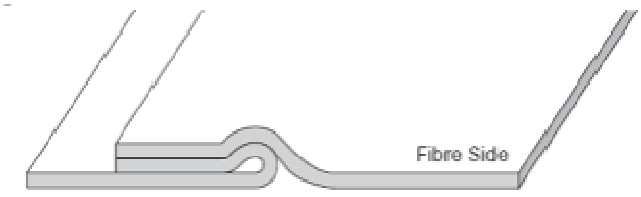

Figure 24. Welding diagram

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Figure 25. automatic thermal welding procedure.

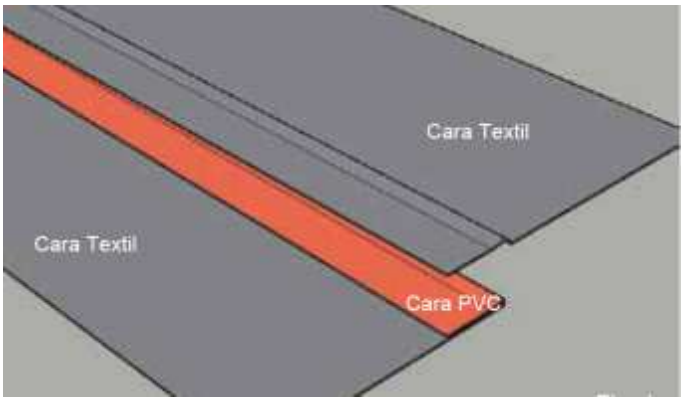

Figure 26. Welding diagram

Figure 27. Appearance of a welded join.

5.3 *Ditch lining.*

MdH can be rapidly unrolled to form a hardened, water proof, concrete ditch. It will conform to a range of ditch profiles and curves and requires no specialist plant equipment for installation. MdH has a design life of 50 years and is significantly quicker and less expensive to install compared to conventional concrete ditch lining.

5.3.1 *A rural road in Córdoba*

The Diputación de Córdoba has specified CC5 for the construction of ditch lining on a rural road in Córdoba.

Figure 28. Ditch lining.

Figure 29.Appearance of the ditch.

5.3.2 *Ditch lining with Manta de Hormigon vs ditch implementation of alternative strips.*

The Dirección General de Carreteras de Castilla-La Mancha conducted a trial ditch lining using MdH next to a ditch of conventional concrete lining. Ease of construction with MdH. Further illustrated in Figure 31.

Figure 30. MdH ditch next to a conventional ditch

Figure 31. Ditch lining with MdH.

5.3.3 *Down ditch lining on slope treatment on the High Speed line Antequera-Granada.*

figure 32. CC5 was specified to build several down ditch linings.

5.3.4 *Construction of a deep ditch lining.*

As part of an ongoing programme, Enterprisemouchel needed to clear and repair an interceptor drain adjacent to the M4 road. MdH provided a solution that prevented erosion, suppressed weed growth and eliminated maintenance issues. MdH enabled simple and cost effective cascades to be constructed using concrete bagwork, over which the Canvas was easily laid. Due to the size of the drain the Canvas was laid across the width allowing a 20m section to be laid by a team of 3 workers in only 1 day.

Figure 33. Deep ditch lined with MdH.

5.3.5 *Siphon chambers reparation. Dueñas, Spain.*

Figure 34. Siphon lined with MdH.

The irrigation facilities of the “Confederación Hidrográfica del Duero” were having problems with several siphons. The inlet and outlet chambers were losing water and needed to be adequately water-proofed. For that purpose, MdH was tailored and welded together offsite prior to installation. The Canvas was tailored to the internal shape of the chamber and placed inside the chamber using a small truck crane. Hilti nails were used to attach the MdH on top of each chamber. Once the Canvas was in place, water was sprayed over the surface to hydrate the MdH.
The chambers were successfully sealed.

Figure 35.Tailored canvas was discharged before its placement.

Figure 36. Tailored canvas placed inside the siphon before being hydrated.

5.4 *Pipe protection.*

MdH can be used as practical, simple to install coating for pipeline protection. MdH is flexible prior to hydration and can be wrapped around the pipe to provide mechanical protection, negative buoyancy and backfill protection of anti corrosion coatings.
The unique properties of CC make it suitable for the most demanding pipeline applications. In remote areas it can be used to coat steel pipe on site without setting up expensive fixed wet concrete application plants. It can be used wherever the following properties are required:

- Rapid strength gain.
- High impact and tear resistance.
- Abrasion and sag resistant when hardened.
- Heat resistant for high temperature or fire proofing applications.
- Chemically resistant for situations subject to chemical attacking as aggressive soil conditions or in inter tidal marine areas.
- Underwater setting (including seawater), ideal for subsea applications

5.4.1 *Protection of a 1200m shallow water pipeline in Qatar*

Iberdrola, an international energy company, commissioned Doha Engineering Services Co. to provide protection for a 1200m shallow water pipeline carrying water and chlorine for their facility in Qatar. CC13 was specified to provide impact protection and negative buoyancy to the 6” diameter PVC pipe. The CC was installed in-situ at a depth of 5m below tidal waters. Divers were able to line approximately 60m of pipeline per day. The MdH was cut into sections on site which were latitudinally wrapped around the pipe and fixed in position using heavy duty cable ties. MdH can be hydrated using seawater, so the MdH set underwater providing a durable and impact resistant protection.

Figure 37. Pipe protection made with MdH under sea water.

5.5 *Mining applications*

A water control application has been used recently in a coal mine in South Wales. We were not allowed to use cameras in the mine hence the diagram.
In certain sections of the access tunnel to the mine, water ingress past the corrugated steel was very bad and causing problems in the mine. Concrete Canvas was used to take water falling through the roof and channel it to the sides where drains were situated.
The good thing about this system is there was a small gap between the support beams and the steel plates which meant MdH could be wedged in between and retained whilst keeping the number of fixings through the steel at a minimum.

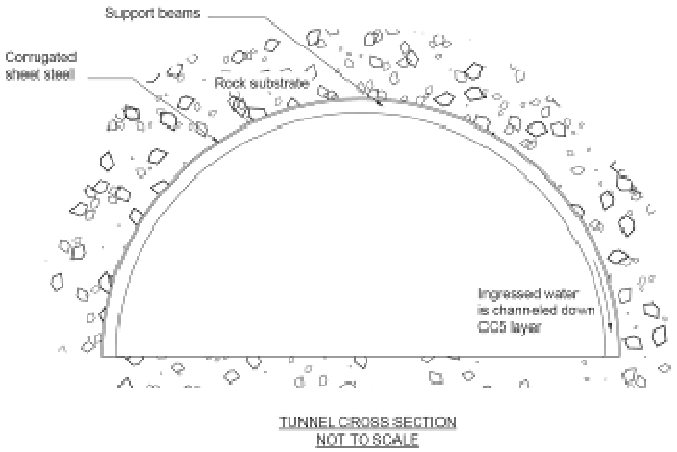

Figure 38. Cross section of the solution.

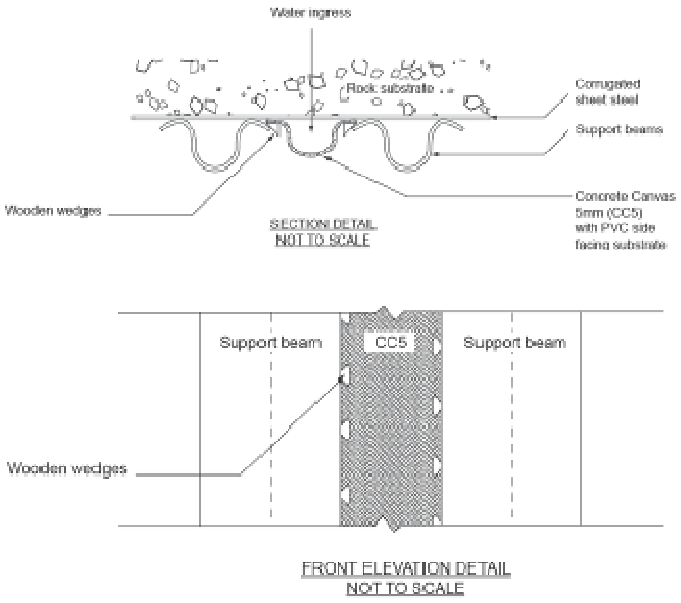

Figure 39. the detailed design of the adopted solution.

6 APPLICATIONS PROJECTED

We´ve chosen among many others to present some of the new applications.

6.1 *Electrical substations*

Figure 40. Slope on electrical substation in the Ascó nuclear Power Station which is going to be covered by MdH.

The placement of MdH on various electrical substations is expected, among others is the Ascó nuclear Power Station.
In electric substations no solids should be allowed to enter the site to avoid the risk of electrical arcing.
The advantages of slope protection with MdH are:
No projections of material on the substation during the installation.
It is possible to work in a limited space so as not to interfere with the substation operation.
Minimum electrical discharge is needed.
Pegs and screws are made of plastic to avoid the risk of arc interrupting.

6.2 *Waterproofing and covering of irrigation pond*

MdH is intended to be used at the construction of "Irrigation pond in Aplicat, Lérida"
MdH offers the following advantages:
It can be applied in steeper slopes, because it can be soil nailed.
Fire resistant.
Once set, it can´t be separated from the ground due to wind or water.
It will not creep.
No concrete or rock protection is required.
It´s not eroded by wave water action.
It won´t be damaged by a water drop from a fire extinguishing helicopter

7 CONCLUSIONS.

MdH is a ground breaking material, rapid, resistant, waterproof, fireproof and low carbon.
It can be applied to a wide range of applications, such as ditch lining, erosion control, slope protection and stabilization, waterproofing, cable and pipe protection, and many others.
It lasts for 50 years and is a more suitable material for almost every application than other geosynthetic.
It's a suitable solution for flooding defenses and can even be laid under water, it hardens in 4 hours.

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