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The Coastal Abrasion Mitigation Using Permeable Structure at The Sipora Island

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Abstract. Abrasion is the beach erosion process due to destructive waves and currents, which are sometimes difficult to handle. The abrasion is caused by current, tidal, wind, and the earthquake and tsunami, 2010. Sipora Island is a world tourist destination for snorkeling, diving, and surfing. This research was conducted to mitigate abrasion at Sipora using a submerged permeable structure. The method is a quantitative analysis using permeable structure, WQC TOAA, current meter, and sediment trap. The field survey was conducted in August and October 2020 using purposive sampling at Kampung Dusun, Tua Pejat, The Sipora Island. The results show that the permeable structure can reduce the abrasion, current, and wave pressure and increase sedimentation at Kampung Dusun. The abrasion rate is 3.73 m/year or 268 m^2/year, classified as very high (CVI). Sedimentation is created behind the permeable structure, whose rate is 9.389 cm3/day, sea current is 0.02-0.08 m/s (reduced till 50%), and wave pressure is 0.375 KN/m^2 (decreased 62.5%). For seawater quality, the pH and turbidity are increased; TDS and salinity are relatively stable at some points, but the pH and temperature of the dissolved oxygen are decreased. The permeable structure can reduce abrasion and create sedimentation at Kampung Dusun, Sipora.

Keywords: Abrasion mitigation; permeable structure; The Sipora Island.

INTRODUCTION

Abrasion is one of the coastal problems in Indonesia. Abrasion occurs because of an imbalance in sediment transport from and to the coast when the volume and area of sediment eroded by seawater is greater than the sediment that settles on the beach [1], [2]. Abrasion can be caused by earthquakes, tsunamis, storms, sediment supply, sea level rise, hydrodynamic and land use [1], [2], [3], [4], [5]. Small islands have essential functions as residential areas, conservation, territorial boundaries, and the existence of a country's sovereignty. Some abrations in Indonesia cause coastal line changes and damage to mangroves [6]; impacts on livelihood and culture [7], [8], [9]. The Kampung Dusun is located in Tua Peijat, The Sipora Island [10]. Tua Peijat is vital as the capital city of the Mentawai Islands Regency, with abundant natural resources and beautiful nature that attract tourism, but Sipora is an underdeveloped region. The Hindia Ocean surrounds Sipora Island, so it is vulnerable to disasters, i.e., earthquakes and tsunamis. Heavy rainfalls, strong currents, and waves make this island prone to abrasion. The climate in Sipora is influenced by the global phenomenon of dipole mode, which results in the circulation of the Monsoon season and the Inter-Tropical convergence [11], [12]. Based on the Indonesia Earthquake Prone Map, Sipora Island is categorized as a high-risk area with a scale MMI V –VIII (MMI) and gravity acceleration >0,35g [12]. The abrasion becomes the main problem at Sipora because it triggers floods, reduces the coastal line, reduces the area for living, and destroys some parts of houses, buildings, and docks like foundations and piles, causing difficulties in mooring, etc. The limitations of coastal protection are usually at the cost and time. This permeable structure provided cheap, simple, green/renewable, and temporary coastal protection. This research aims to know the effectivity of permeable structure to mitigate abrasion at Kampung Dusun by indicates:

1) Sedimentation process to restore the coastal line.
2) The change in seawater quality.
3) The reduction of current velocity and wave pressure.

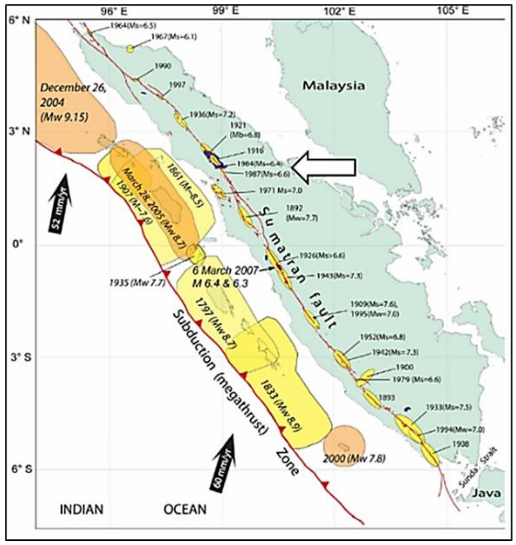

FIGURE 1. The Earthquake History at Mentawai Island and Western Sumatera Island

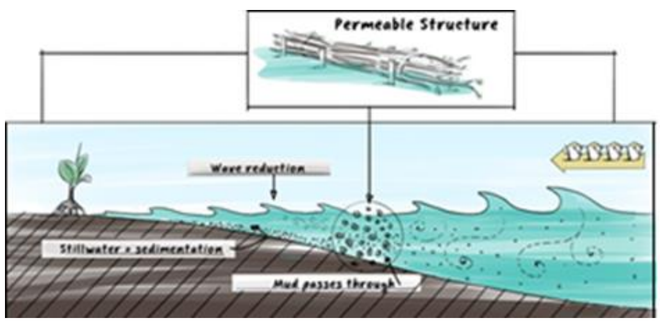

FIGURE 2. Permeable structure to reduce abrasion [14]

FIGURE 3. Sedimentation behind coastal protection structure [1]

METHODOLOGY

This research method is a quantitative analysis based on a field survey with purposive sampling and implemented a permeable structure. Some variables were measured, i.e., abrasion rate and coastal line changes based on CVI and CDA, sediment rate, sea current velocity, wave pressure, and seawater quality. CDA is a method used to analyze abrasion at Takisung, South Kalimantan Province [15]. The instruments used are a ruler, current meter, GPS, WQC TOAA, and sediment tubes. A submerged permeable structure containing wood, leaves, and stones wrapped by a net (1.5m x 0.8m x 1m) was implemented. The area of abrasion from the year 2008 to 2018 is measured based on a Google imagery map and then classified into levels according to **TABLE 1** and **TABLE 2**. **FIGURE 4** shows the research location, and **FIGURE 5** shows the abrasion at Kampung Dusun. The field survey was conducted on 5-12 August 2020 and 5-12 October 2020 at Kampung Dusun, Sipora. The time of the study is based on periods of the highest tides that occurred. This location was chosen because of the level of abrasion and the urgency of saving people’s lives on a small, underdeveloped island. Still, it has significant potency for the economic sector as a tourism destination. The submerged permeable structure was used because that condition allows water exchange and small ships can pass; hence, they do not have to turn around their fishing track or routes, which is cheaper or economical.

TABLE 1. Abrasion level based on CVI.

Level	Classification				
	VL	**L**	**M**	**H**	**VH**
Coastal line (m/year): - Erotion/Abrasion - Acretion/sedimentation	>2.0	1.0 – 2.0	1.0 – -1.0	1.0 – -2.0	< -2.0

Note: VL = Very Low; L = Low; M = Medium; H = High; VH = Very High

TABLE 2. Abrasion level based on CDA (Public Work Ministry Regulation7 08/SE/M/2010).

Level	Criteria of abrasion
Low	The coastal line is forward and backward but still stable.
Medium	Coastal line backward < 1 m/year.
High	Coastal line backward 1 m – 2 m/year.
Very High	Coastal line backward 2 m – 3 m/year.
Extreme Very High	Coastal line backward > 3 m/year.

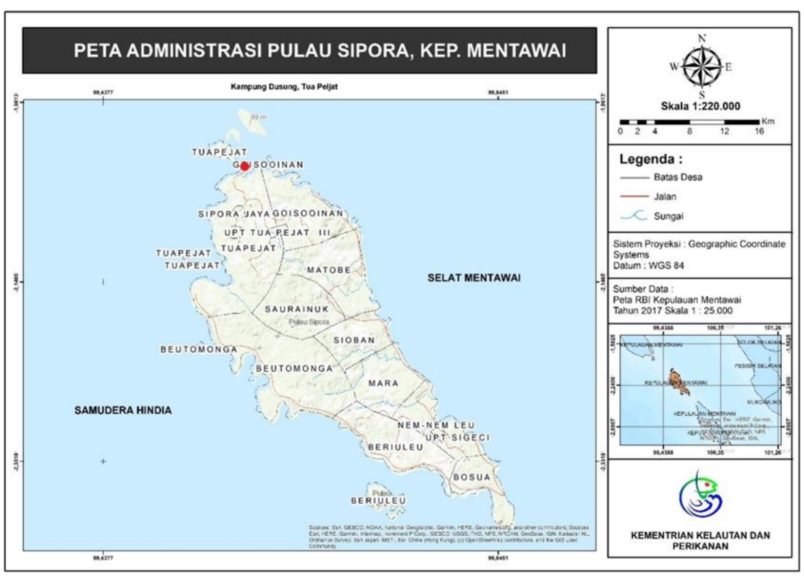

FIGURE 4. Research Location at Kampung Dusun, Tua Peijat, The Sipora Island

RESULT AND DISCUSSION

Most previous papers about abrasion use GIS or Google Earth imagery to measure the abrasion, which is the same as one of the methods in this paper. Some other papers use mangrove damage and hydrodynamic, such as tidal and wave height, to measure the abrasion. The difference with this paper is that it uses seawater quality analysis, sediment analysis, current velocity, and wave pressure as hydrodynamic parameters to measure the effectivity of permeable structures to reduce or mitigate abrasion. For almost one decade (2008-2018), Dusun village suffered an abrasion of about 1,608 m2, with an abrasion rate of 3.73 m/year or Very High based on CVI (**TABLE 1**). Based on the regulation of Indonesia Public Work and Housing Ministry No.08/SE/M/2010, the abrasion at Dusun village is classified as exceptionally Very High (**TABLE 2**). The abrasion and high rainfall caused floods and covered some local roads and residence areas of Kampung Dusun, about 30-40 cm in height. The tidal of Sipora Strait is *a mixed prevailing semidiurnal tide; the highest tide is 1.82 m, and the lowest tide is 0.62 m, with the tidal range being* 1.2 m. The velocity of sea current is 0.2 – 0.35 m/second, and wave significant height is 2 m 10 (CMGA, 2020). The coastal slope is about 7° - 11, and the beach elevation is down about 60 – 70 cm because of abrasion. The level of damage cost is 211.5, which is classified as heavy damage with top priority for rehabilitation [16]. **FIGURE 6** and **7** show the sediment traps and the location of the permeable structure. **FIGURE 8** shows that sediment contains sand and mud.

FIGURE 5. Abrasion at Kampung Dusun, Tua Peijat, The Sipora Island

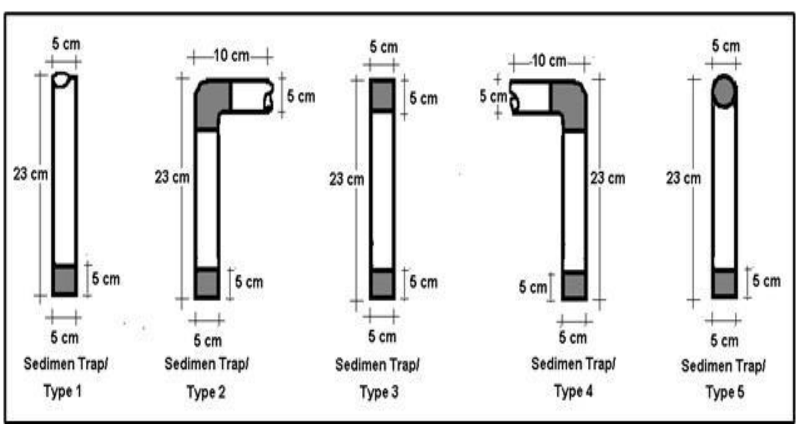

FIGURE 6. Types and sizes of sediment tubes

FIGURE 7. The location of permeable structures and sediment traps

There are two layers, which are sand and mud. The parameter of sediment is seen in **TABLE 3**.

FIGURE 8. The result of the sediment trap at Point 1

TABLE 3. Parameter of sedimen.

							Point 1								
Parameter	**Type 1**			**Type 2**			**Type 3**			**Type 4**			**Type 5**		
Mass (gr)	16.2	13.3	8.5	13.6	12.0	12.8	13.6	12.0	12.8	13.6	12.0	12.8	14.4	13.3	9.6
Density (gr/cm^3)	2.66	2.66	2.66	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.66	2.67
Volume (cm^3)	9.46 cm^3/day			9.53 cm^3/ day			9.53 cm^3/ day			9.53 cm^3/ day			9.26 cm^3/ day		
Sedimentation	0.032 gr/cm^2/ day			0.032 gr/cm^2/ day			0.032 gr/cm^2/ day			0.032 gr/cm^2/ day			0.032 gr/cm^2/ day		
							Point 2								
Parameter	**Type 1**			**Type 2**			**Type 3**			**Type 4**			**Type 5**		
Mass (gr)	14,6	12.2	9.3	14.4	13.3	9.6	13.6	12.0	12.8	14.4	13.3	9.6	13.6	12.0	12.8
Density (gr/cm^3)	2.655	2.652	2.657	2.67	2.66	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67
Volume (cm^3)	9.0 cm^3/ day			9.27 cm^3/ day			9.53 cm^3/ day			9.25 cm^3/ day			9.53 cm^3/ day		
Sedimentation	0.030 gr/cm^2/ day			0.031 gr/cm^2/ day			0.032 gr/cm^2/ day			0.031 gr/cm^2/ day			0.032 gr/cm^2/ day		

Sediment trap

There are 2 (two) points of sediment trap location: Point A1, behind the permeable structure, and Point A2, near the beach. As seen in TABLE 3, the sediment at point 1 was dominated by particles from parallel currents and the beach. Particles from perpendicular current dominated sediment at point 2. The sea current direction is west and east (parallel to the coast). The difference in sediment volume between points 1 (V1) and 2 (V2) is 0.73 cm^3/day (V1>V2). The average sediment rate, $v_{s.\ avr,}$ is 9.389 cm^3/day. The total time for sedimentation is 115 days or 3.8 months.

Sea water quality

The seawater quality was measured twice: 7th August 2020 and 7th October 2020 or before and after the implementation of permeable structure—the result of seawater quality at Kampung Dusun as seen in the tables and graphs below. **TABLE 4** and **FIGURE 9** show the water quality condition before the permeable structure was implemented. **TABLE 5** and **FIGURE 10** show the water quality condition after implementing the permeable structure.

TABLE 4. Parameters of seawater quality before PS was implemented/first survey (7th August 2020)

Point	Coordinate		Parameter						Note
	SL	EL	pH	TDS	Salinity	Turbidity	Dissolved Oxygen	Temperature (°C)	
A1	2°1’30”	99°35’15”	8.57	42.4	32	0	26.41	30.7	Outside PS
A2	2°1’38”	99°35’15”	8.56	52.3	31.9	0	47.8	30.7	Between PS and the beach
A3	2°1’47”	99°35’15”	8.57	52.5	32	3.1	26.41	30.7	Near beach

PS = Permeable Structure

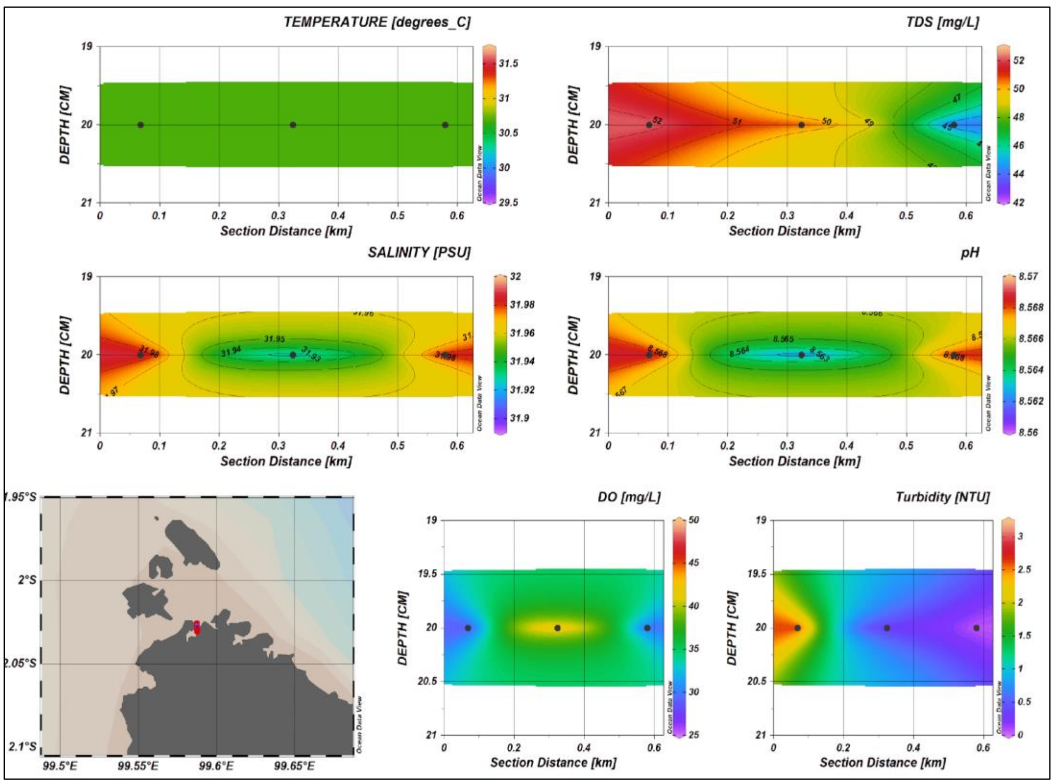

FIGURE 9. The graph of water quality at a location without PS, first survey (7th August 2020)

TABLE 5. Parameters of seawater quality after PS was implemented/second survey (7th October 2020)

Point	Coordinate		Parameter					
	SL	EL	pH	TDS	Salinity	Turbidity	Dissolved Oxygen	Temperature (°C)
A1	2°1’30”	99°35’15”	8.62	49.9	30.6	7.2	6.85	30
A2	2°1’38”	99°35’15”	8.69	49.6	30.2	21.3	6.75	30
A3	2°1’47”	99°35’15”	8.63	7.8	0.7	24.6	6.54	29.4

Source: Field measurement

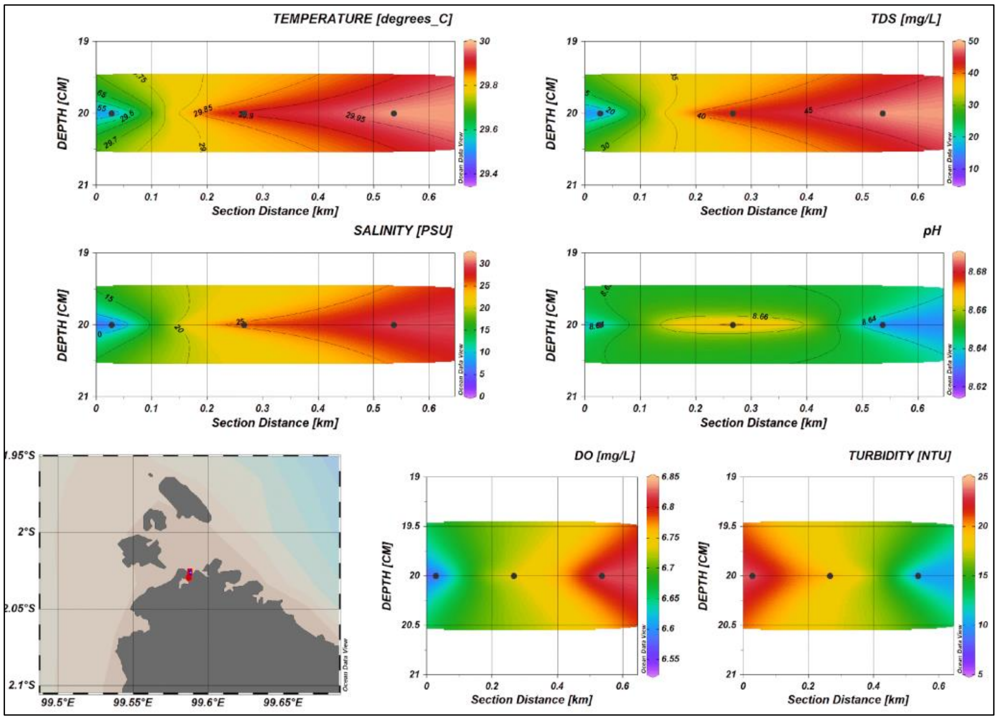

FIGURE 10. The graph of water quality at a location with PS, second survey (7th October 2020)

FIGURE 11 below compares seawater quality before and after PS was implemented.

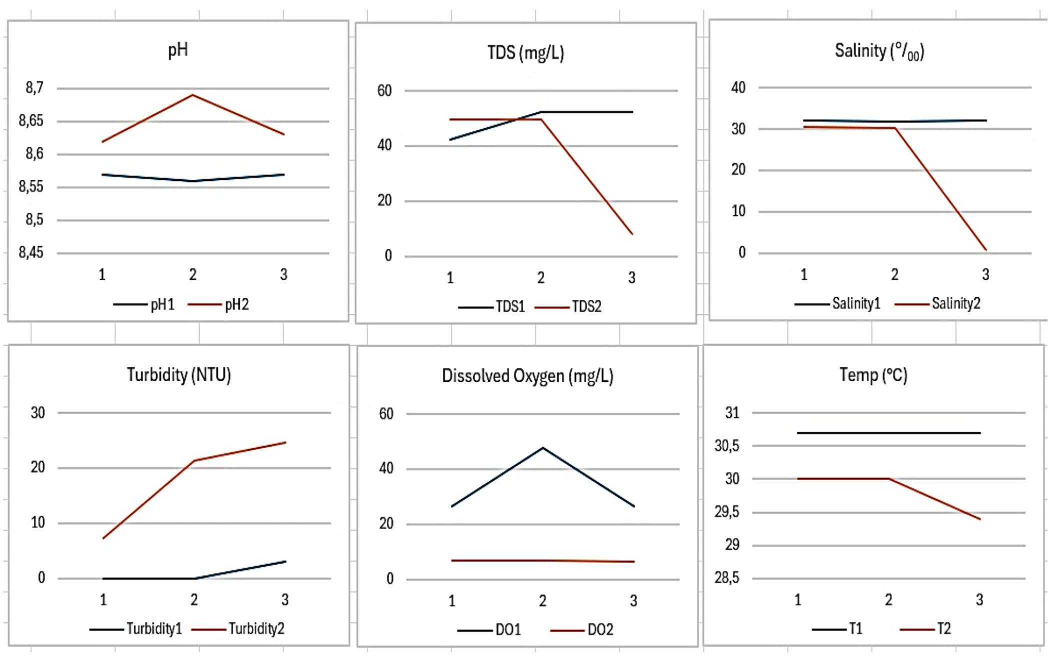

FIGURE 11. The comparison of water quality in the first and second survey

As seen in FIGURE 11, pH and turbidity were increased, and TDS and salinity at some points were relatively stable, but Dissolved Oxygen and temperature were decreased. **TABLE 6** shows the current velocity and wave pressure before (without PS) and after PS (with PS) implementation. The result is v1>v2 and P1>P2.

TABLE 6. The current velocity and wave pressure at the permeable structure.

1. The current velocity without permeable structure, v1 (m/s)			2. The current velocity with permeable structure, v2 (m/s)		
A1	A2	A3	A1	A2	A3
0.2	0.2	0.2	0.2	0.02	0.08
Wave pressure, P1= 1 KN/m^2			Wave pressure, P2 = 0.375 KN/m^2		

Permeable structure is an alternative for coastal protection. Depending on the type of beach, many types of coastal protection can be applied to prevent abrasion. The coastal protection could consist of soft and hard structures i.e. greenbelt (MRC, 2018), groin and breakwater [17]; [18]; [19]; [1], geotextile [20], revetment (Pratikto et al., 2014), hybrid engineering [14] and reclamation (CUR, 1987; Ministry of Human Rights and Law, 2007; Yuwono et al., 2010). However, using massive structures for sand beaches with fast currents, strong waves, and high tides is better. Permeable structures are usually implemented on muddy beaches and calm waves.

CONCLUSION

Abrasion at Kampung Dusun is categorized as very high level based on CVI and highly high level based on regulation. The abrasion is 1,608 m^2 with a rate of 3.73 m/year. To prevent abrasion, the permeable structure shows performance by reducing the sea current velocity and wave pressure. It also creates sediment at the back of the structure, with an average sediment rate of 9.389 cm^3/day. The seawater quality shows the sedimentation process by increasing some variables, i.e., turbidity and TDS. The recommendation for the following research is an analysis of abrasion mitigation using hybrid coastal protection.

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