تقدير كمية الرمال المنقولة بالرياح بطول شاطئ مدينة لبده و أثرها على منشات لبده الأثرية – ليبيا

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ملخص

يتميز الشاطئ المطل على البحر المتوسط لمدينة لبده الأثرية بأنة من النوع الصخري فى أغلبة، بينما يصبح الشاطئ غربا رمليا حيث يحاط بالكثبان الرملية. يتخذ الشاطئ الرملي اتجاه شمال ٧٠ غرب – جنوب ٧٠ شرق، و يتحكم مقدار و اتجاه الرياح السائدة، و كذلك اتجاه خط الشاطئ فى تحديد كميات الرمال المنقولة بالرياح سواء فى اتجاه البر، أو اتجاه البحر، و لقد أظهرت نتائج توزيع الرياح المؤثرة بمنطقة الدراسة أن الرياح النشطة يغلب عليها الرياح الشمالية الغربية . تم تمثيل الشاطئ الرملي لمنطقة الدراسة بعينات حللت ميكانيكيا لحساب الحجم المتوسط، ومن ثم حساب كميات الرمال المنقولة بواسطة الرياح، وذلك بتطبيق معادلة كاديب (١٩٦٣)، والتى أظهرت أن أكبر كميات الرمال المنقولة من الشاطئ كانت خلال فصل الربيع.

يمثل الشاطئ الرملي لمدينة لبده الأثرية مصدرا للرمال حيث تميز شاطئ مدينة لبده الأثرية بمحصلة نقل للرمال باتجاه البر مما أدى الى تكوين كثبان رملية ساحلية تحيط بالشاطئ الرملي، وامتد تأثيرها الى المنشات الأثرية، و من خلال هزة الدراسة تم اقتراح توصيات من أجل حماية منشات مدينة لبدا الأثرية.

ASSESSSMENT OF SAND TRANSPORTED BY WIND ALONG THE ANCIENT LIBDA CITY BEACH AND ITS IMPACT ON THE ANCIENT CONSTRUCTIONS, LIBYA

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ABSTRACT

The beach of Libda city extends for about 7 km. The shoreline orientation is mainly N70W-S70E. The relation between the direction and duration of the dominant wind, and the orientation of the shoreline governs the net sand transport budgets, toward sea or toward land. The northwestern beach of Libda city is sandy and bordered by sand dunes. On the other hand, the beach becomes rocky toward east and is nearly devoid of sand dunes. The sandy beach is sampled and the mean grain size was obtained for sand transport calculations. The transport budgets along the beach were calculated according to Kadib (1963) formula. The highest transport rate is recorded during spring. Large amounts of sand have been and continue to be removed from the beach by wind landward and accumulate as sand heaps and sand dunes bordering the sandy beach of Libda City. Severe sand encroachment occurs along the western coast of Libda city. Recommendations for the protection of the ancient Libda city constructions are given.

INTRODUCTION

Wind power moves surface materials, either directly as wind blown or indirectly by waves (Strahler and Strahler, 1997). Although aeolian activities are natural processes, they become a problem when they approaches an inhabited area. Therefore, the assessment of sand transported by wind is of utmost importance for planning and constructing coastal structures.

Several specialists have developed equations for computing sand drift, while others established practical devices for direct collection of transported sand. Bagnold (1941) established a formula that was modified by Kadib (1963) for the calculation of sand transported by wind along natural beaches. Rosen (1978) established a device called sand trap, a system of monitoring the total aeolian transport in coastal sand dunes environment, which directly collects wind laden sand.

The nature of the surface, the shape and density of the particle and the force of collision that set particles in motion determine the height to which a grain will saltate. A grain propelled from a soft bed of sand can attain a height of only 50 centimeters or less, whereas a grain may saltate to a height of 2 meters from a surface covered by a continuous pavement of stones (Chernicoff and Venkatakrishnan, 1995).

The amount of sand budget is adopted by using the Bagnold's equation, which seems to be superior to any other formula, because it consider the grain size diameter of the sediment.

Libda city lies about 3 Km east to Al-Khums city and about 130 Km east to Trapoli (Fig. 1). According to the Meteorological Authority data of Al-Khums station, the climate of the study area is generally semi arid (rainfall ranging between 200 to 250 mm/y). Summer is generally hot and dry with temperature ranging from 15 to 40^0c, while winter is occasionally rainy and cool with temperature ranging from 0 to 25^0c. Humidity is ranging from 60 % to 75 %. Active winds, in general, blow from northwest during summer and southwest during winter.

The aim of this study is to determine the sand transport rates and the quantity of aeolian sediments that have harmful effect on Libda city (Fig. 1).

MATERIALS AND METHODS

Detailed wind data during the years 2000-2001 were obtained from Al-Khums Meteorological Authority. The wind data represent the wind speeds every three hours for 36 wind directions. The durations in hours of winds of various speeds from various directions were calculated and summed up as seasonal and annual summaries.

Ten spot sand samples were collected at 100-m interval along the sandy beach (Fig. 1). The grain size analysis of the encountered beach sediments was carried out using the standard sieving technique of Folk and Word (1957).

Calculations of the seasonal and annual budgets of sand transport rates along the beach were obtained according to the methodology of Kadib (1963) that depends on the expression of Bagnold (1941).

$$Q = C.L.T.\sqrt{d/D} \,.\, \gamma/g.\, U^{*3}$$

Where,

Q = Total transport in pound per year.

C = Bagnold constant, and has the following values:

1.5 for a nearly uniform sand,

1.8 for naturally graded sand,

2.8 for sand with a very wide range of grain diameter.

L = Length of the beach in feet perpendicular to direction of wind considered.

d = Average grain diameter of sand considered (d_{50} mm).

D = Average grain diameter of standard sand (0.25 mm).

γ = Specific weight of air (0.76 1bs/ft^3).

U*= Shear velocity of wind in ft/sec.

T = Average duration of wind in seconds per year.

g = Acceleration due to gravity (32.2 ft/sec^2).

By substituting the values of the above mentioned parameters and choosing C = 1.8, since the sand considered is naturally graded, the following equation is obtained:

$$Q = 15.2 \sqrt{d/D} . U*^3 t . L$$

Where "t" is wind duration in hours per year.

Duration of winds of various speeds from various directions was calculated from the wind summaries and the shear velocity was obtained by using Kadib (1963) procedures as follows:

$$U* = \{U - U`\}/ \{6.13 \text{ Log } Z/Z`\}$$

Where,

U = is the velocity of wind at a standard height (Z) equals to 32.8 ft above the sand surface,

U\`, Z\` and U* were calculated according to Kadib (1963) as shown in Tables (1 and 2).

RESULTS AND DISCUSSION

Sedimentomorphic Classes:

Libda area shows two main sedimentomorphic types, namely beach and sand dunes. Libda beach is mainly rocky and characterized by wave cut cliffs, wave related furrows and ridges, sea platforms and sea stacks. Steep cliffs are at or just landward of the shoreline and rise up to 1.2 m above the water level (Elatrash et al., 2006). The beach becomes unconsolidated sandy west to Libda sea port and bordered by sand dunes (Fig. 1). The dune types, orientations and patterns are controlled by the wind directions and the topographic conditions (Draz, 1997). The dominant sand dune type is the barchanoid dunes. These dunes attain heights up to 4m. Barchanoid dunes form when sand supply is greater than that of barchan dunes (Wasson and Hyde, 1983).

Wind Regimes:

The magnitudes and directions of the incoming winds were presented graphically to delineate the prevailing wind regimes, in the form of seasonal and annual wind roses (Fig. 2). The speed categories below the threshold velocity of moving dry and loose sand (< 12 knot) are considered non-effective (Kadib, 1963 and Fryberger, 1979). Thus, the magnitudes of all speed categories more than 12 knots are represented as percentages of occurrence for all wind directions (Fig. 2).

The annual wind regime reveals a dominance of the northwesterly wind. In general, the active winds blow mainly from northwest during summer and southwest during winter and gradual transition is well observed during spring and autumn (Fig. 2). However, The effective winds almost strike Libda city from northwest (Figs. 1 and 2).

Lengths of the Perpendicular Projections:

Libda beach is extending nearly N70W-S70E. Considering the studied wind directions, there are five wind directions contributing landward sand transport and their opposite directions cause seaward transport (Fig. 3). The lengths of the perpendicular projections of Libda beach to the wind directions are measured and shown in Fig. (3).

Transport Calculations:

The calculated landward and seaward (U^{*3} t . L) values are shown in Tables (3 and 4); while the calculated amounts of sand drift are given in Table (5) and Fig. (4). The highest amount of landward sand transport is observed during spring (7.1 m^3/m); while the lowest amount of sand transport is observed during autumn (1.9 m^3/m).

The estimated annual landward sand transport (16.5 m^3/m) is greater than that transported seaward (6.6 m^3/m). This may explain the occurrence of coastal sand dunes bordering the unconsolidated sandy beach. The calculated amount of

NW sand budget which strike the ancient constructions of Libda City is 11.2 m^3/m (Table 5).

Impact of winds on the Ancient Constructions

Field observations show that, the effective winds almost strike Libda city from northwest and the ancient Libda city constructions behind the western sandy beach are severely affected by wind erosion (Figs 5 and 6). Wind abrasion pits the blocks of ancient Libda constructions and deep groves are observed on the side that faces the prevailing wind direction (Fig. 6). Moreover, wind-built mounds and ridges of sand are accumulated at the wind shadow of the ancient construction blocks (Figs 5 and 6).

The removal of large quantities of beach sediments from the western beach may be related to its loose sediments covered with little vegetation compared with that of the rocky beach. This may give an indication about the necessity of stabilization of the sand dunes bordering the northwest sandy beach. Stabilization of the mobile sand dunes can be achieved by the development of vegetation cover. The vegetation cover anchors the soil and holds its particles down. Hegedoment et al. (1977), recommended species for sand dune stabilization such as *Tamarix aphylla, Acasia salicina, Panicum turgidum and Retma raetam*. However it is recommended to depend on local adapted vegetation.

CONCLUSIONS

Libda beach is mainly rocky and becomes unconsolidated sandy bordered by sand dunes west to Libda sea port. Large amounts of sand have been and continue to be removed from the beach by wind and accumulate as sand heaps and sand dunes bordering the sandy beach of Libda City. The estimated annual landward sand transport (16.5 m^3/m) is greater than that transported seaward (6.6 m^3/m). This may explain the occurrence of coastal sand dunes bordering the unconsolidated sandy beach. Barchanoid sand dunes is the dominant type which form when sand supply is greater than that of barchan dunes**.**

The highest amount of landward sand transport is observed during spring (7.1 m^3/m); while the lowest amount is observed during autumn (1.9 m^3/m).

Severe sand encroachment occurs along the western coast of Libda city. The effective winds almost strike Libda city from northwest. The calculated amount of NW sand budget which strike the ancient constructions of Libda City is 11.2 m^3/m. The ancient Libda city constructions behind the western sandy beach are severely damaged by wind erosion. The removal of large quantities of beach sediments from the western beach of Libda city may be related to its loose sediments covered with little vegetation compared with that of the rocky beach. The presence of vegetation protects the surface immediately beneath the plant from erosion and acts as a trap for migrating particles (Wolfe and Nickling, 1993).

RECOMMENDATIONS

To overcome the problems arising from moving aeolian sediments, stabilization of the mobile sand dunes by the development of local adapted vegetation cover and construction of oblique barriers at the direction of the prevailing wind are suggested. Embabi (1987) reported that, the construction of oblique barriers is expected to be a successful method since in nature local relief directs the paths of dune movement and affects wind velocity. This method needs to be tested in the field so that height, length and breadth of the barrier can be determined.

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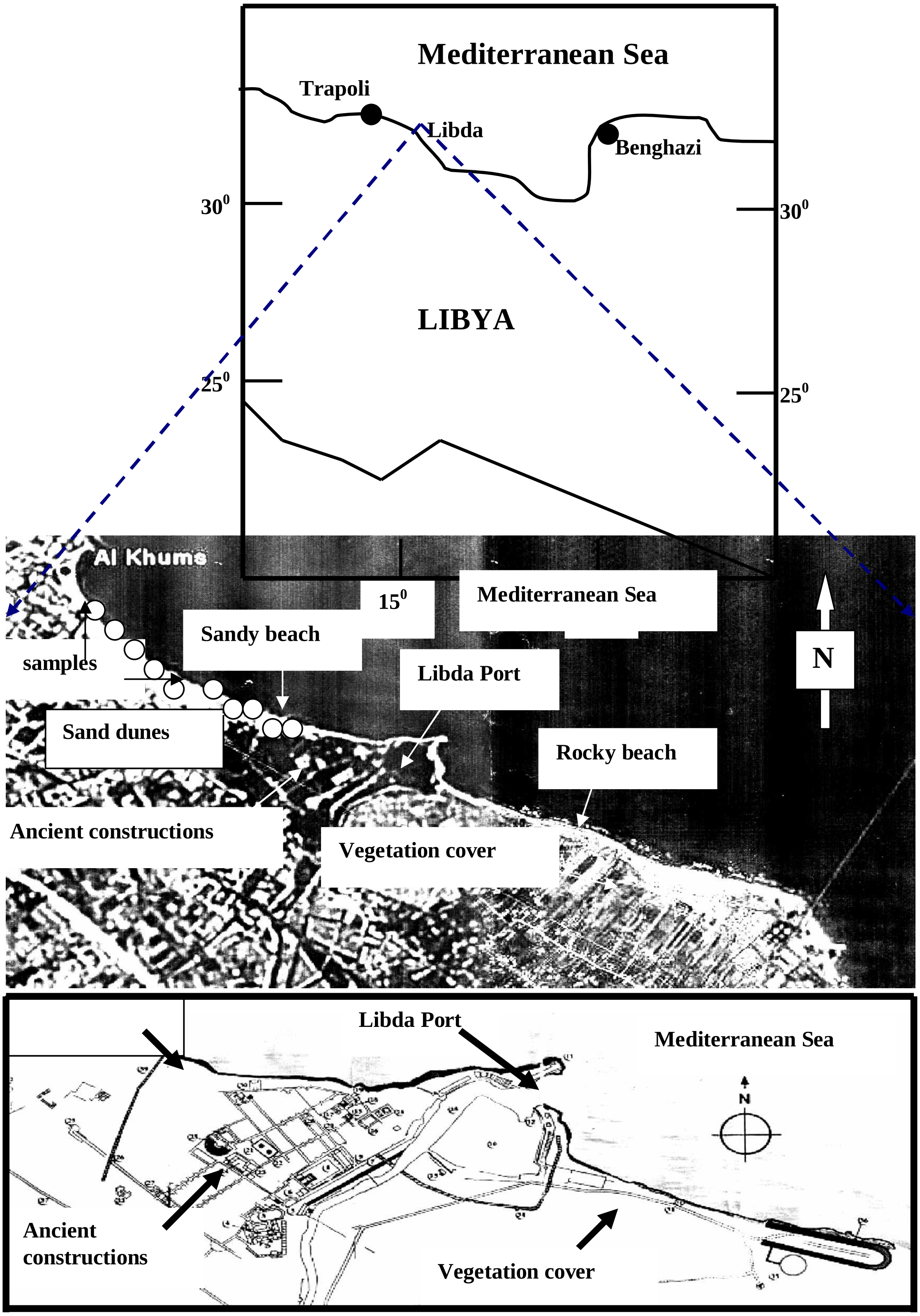

Fig. (1): Locations of the Studied Mediterranean Beaches along Libda city.

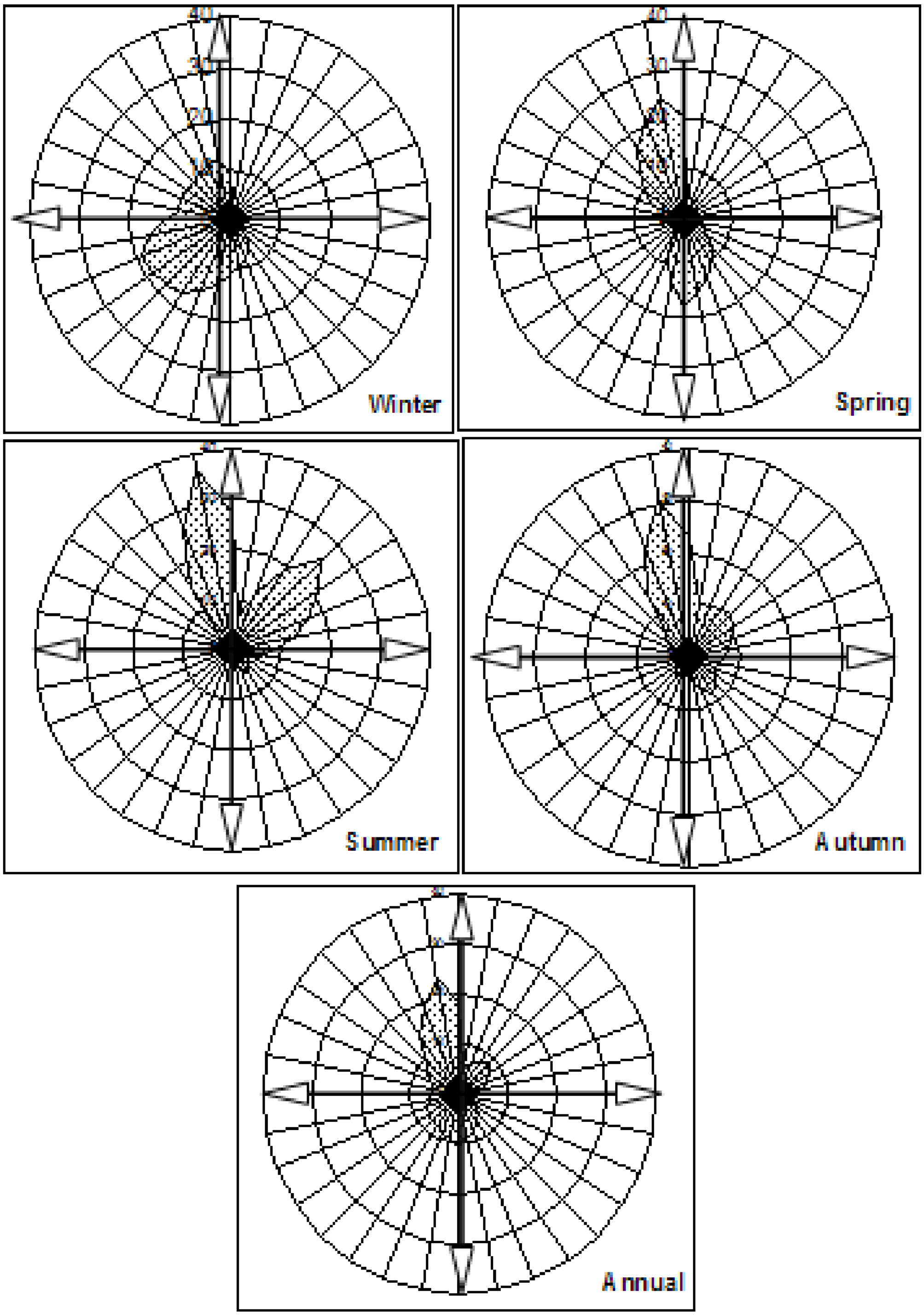

Fig. (2): Seasonal and annual wind roses for Libda area.

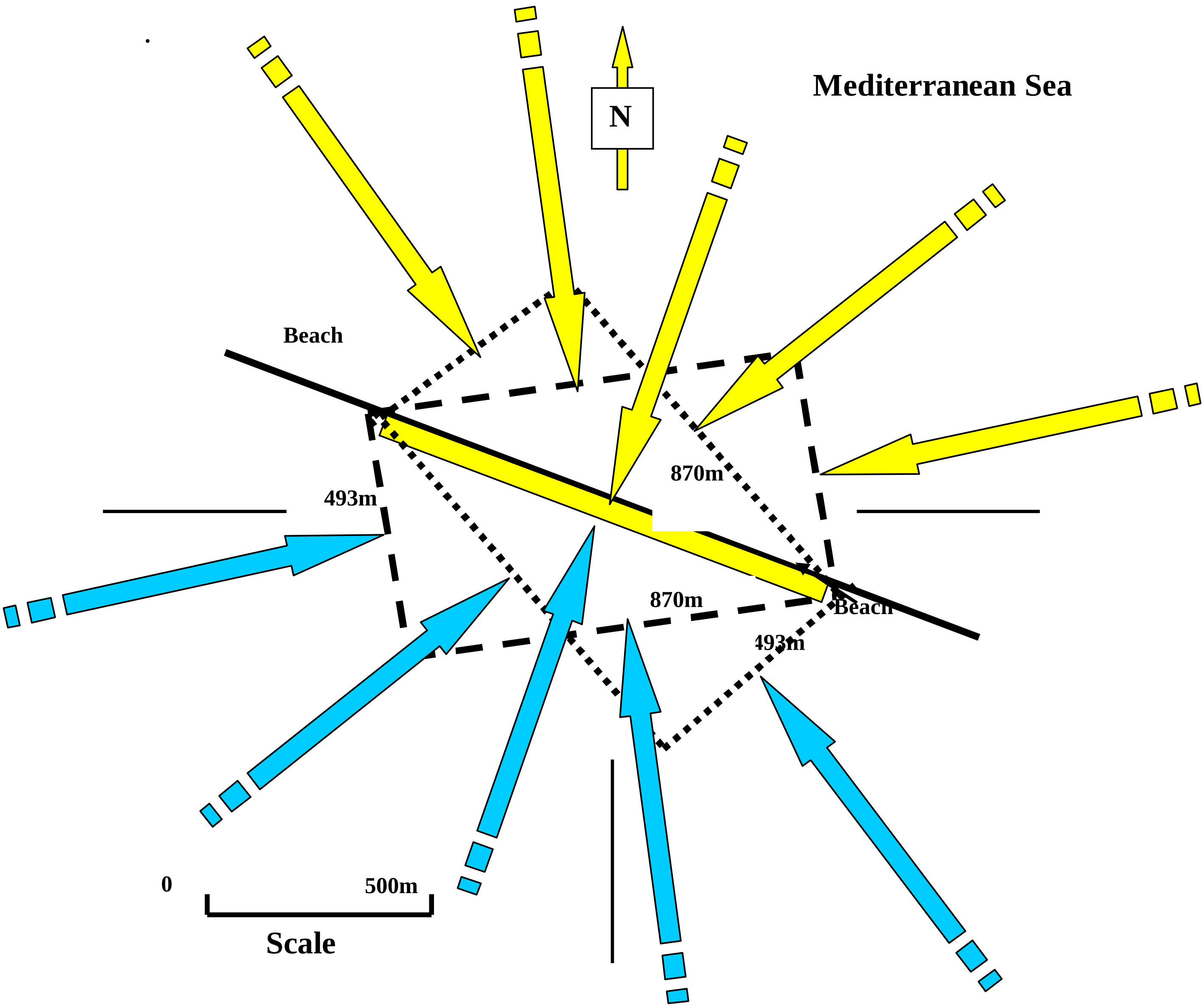

Fig. (3): The lengths of the perpendicular projections of Libda beach to the wind directions are 1000 m (3281 ft), 870 m (2854 ft) and 493 m (1618 ft).

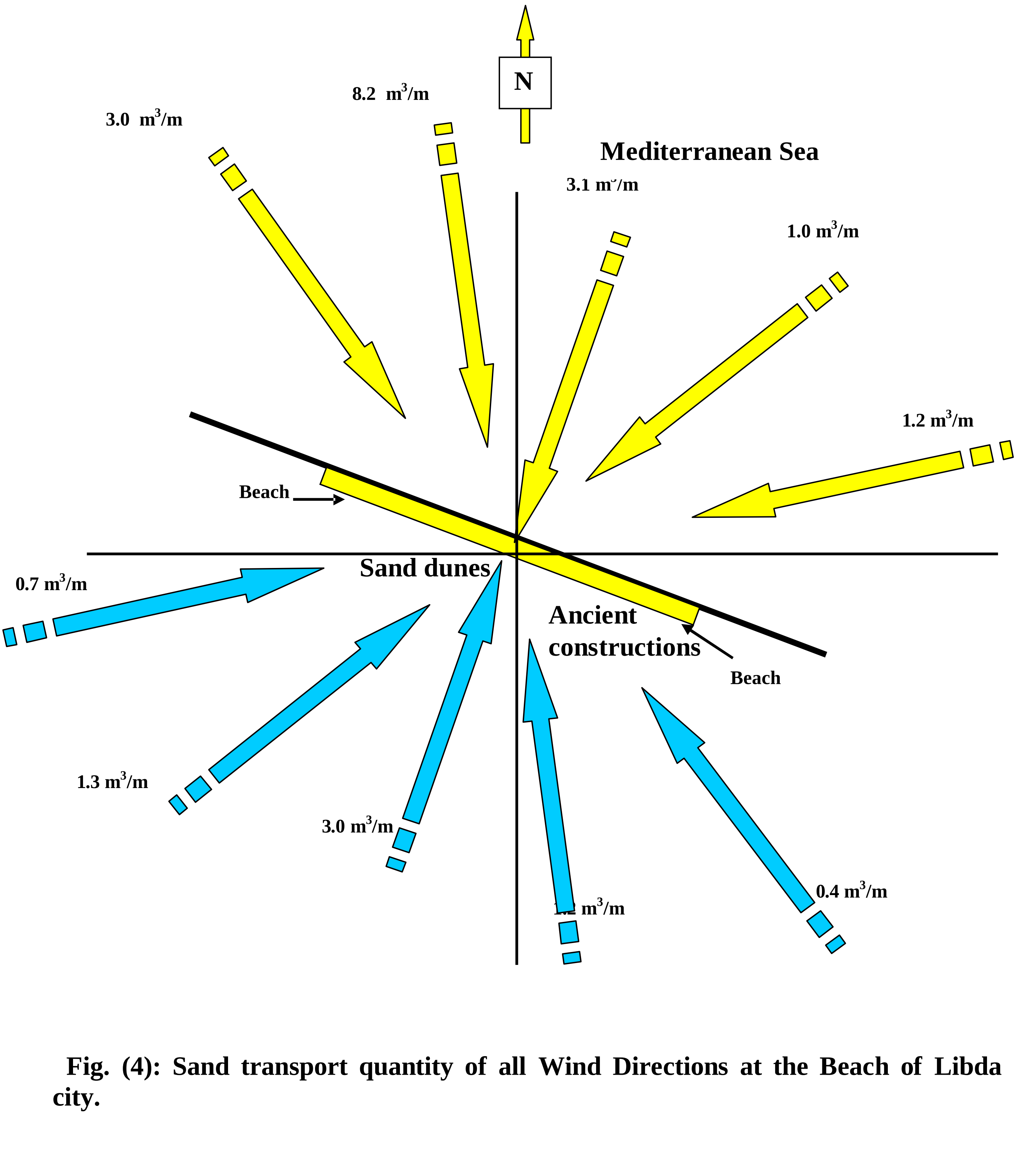

Fig. (4): Sand transport quantity of all Wind Directions at the Beach of Libda city.

Table (1): Calculation of $U^{/}$ and $Z^{/}$ by adopting Kadib (1963). Note, Z = 32.8 ft.

d50 (mm)	**U' = 20 d50 (mile / hr)**	**U' (Ft / sec)**	**Z' = 10 d50 (mm)**	**Z' (ft)**	**6.13 log Z / Z'**
0.2071	**4.142**	**6.076**	**2.071**	**0.006**	**22.91**

Table (2): Calculation of shear velocity by adopting Kadib (1963).

U (ft / sec)	U^{*} = (U – **6.076**) / **22.91**	U^{*3}
22.788	0.729	0.39
32.07	1.135	1.46
41.356	1.540	3.65
51.48	1.982	7.79

Table (3): Calculation of landward $U^{*3}tl$ values.

Season	U^{*3}	$310^0 - 330^0$		$340^0 - 360^0$		$10^0 - 30^0$		$40^0 - 60^0$		$70^0 - 90^0$		Total
		L=1618 (ft)		L=2854 (ft)		L=3281 (ft)		L=2854 (ft)		L=1618 (ft)		
		t (hr)	$U^{*3}tl$	t (hr)	$U^{*3}tl$	t (hr)	$U^{*3}tl$	t (hr)	$U^{*3}tl$	t (hr)	$U^{*3}tl$	
Winter	0.39	51	32182	87	96836	21	26871	39	43409	21	13251	
	1.46	39	92129	33	137506	3	14371	3	12501			
	3.65	15	88586	9	93754	9	107781					
	7.79	3	37813			3	76677					
Total			**250710**		**328096**		**225700**		**55910**		**13251**	**873667**
Spring	0.39	48	30289	159	176977	105	134357	36	40070	36	22717	
	1.46	45	106303	72	300012	30	143708	6	25001	6	14174	
	3.65	39	230322	21	218759	6	71854			3	17717	
	7.79	6	75625	6	133396							
Total			**442539**		**829144**		**349919**		**65071**		**54608**	**1741281**
Summer	0.39	24	15144	165	183655	48	61420	42	46749	132	83295	
	1.46	3	7087	78	325014	12	57483	3	12501	36	85042	
	3.65			6	62503					3	17717	
Total			**22231**		**571172**		**118903**		**59250**		**186054**	**957610**
Autumn	0.39	27	17038	78	86819	33	42226	36	40070	48	30289	
	1.46	6	14174	45	187508	6	28742	6	25001			
Total			**31212**		**274327**		**70968**		**65071**		**30289**	**471867**
Annual			746692		2002739		765490		245302		284202	4044425

Table (4): Calculation of seaward $U^{*3}tl$ values.

Season	U^{*3}	$130^0 - 150^0$		$160^0 - 180^0$		$190^0 - 210^0$		$220^0 - 240^0$		$250^0 – 270^0$		Total
		L=1618 (ft)		L=2854 (ft)		L=3281 (ft)		L=2854 (ft)		L=1618 (ft)		
		t (hr)	$U^{*3}tl$	t (hr)	$U^{*3}tl$	t (hr)	$U^{*3}tl$	t (hr)	$U^{*3}tl$	t (hr)	$U^{*3}tl$	
Winter	0.39	6	3786	21	23374	30	38388	48	53427	45	28396	
	1.46			3	12501	3	14371	12	50002	9	21261	
	3.65					3	35927			9	53151	
	7.79									3	37813	
Total			**3786**		**35875**		**88686**		**103429**		**140621**	**372397**
Spring	0.39	33	20824	102	113532	135	172745	18	20035	15	9465	
	1.46	9	21261	6	25001	33	158079	18	75003			
	3.65					12	143708	6	62503			
	7.79					6	153354					
Total			**42085**		**138533**		**627886**		**157541**		**9465**	**975510**
Summer	0.39	12	7572	0.00	0.00	9	11516	6	6678	3	1893	
	1.46	6	14174							3	7087	
Total			**21746**		**0.00**		**11516**		**6678**		**8980**	**48920**
Autumn	0.39	15	9465	9	10018	9	11516	6	6678	6	3786	
	1.46	6	14174	21	87504			12	50002			
	3.65			3	31251							
Total			**23639**		**128773**		**11516**		**56680**		**3786**	**224394**
Annual	91256		303181		739604		324328		162852		1621221	

Table (5): Seasonal and annual landward and seaward sand drift along Libda sandy beach (1000 m long).

Season	Transport Direction	(Q) Pound ($15.2\ \sqrt{d/D}\ .\ U^{*3}\ t\ .\ L$)	Ton (Pound x 0.0005)	m^3 (Ton / 1.7)	m^3 / m (m^3 / 1000)
Winter	**Landward**	12086751	6043	3555	**3.6**
	Seaward	5151928	2576	1515	1.5
Spring	**Landward**	24089761	12045	7085	**7.1**
	Seaward	13495698	6748	3969	4.0
Summer	**Landward**	13248061	6624	3896	**3.9**
	Seaward	676784	338	199	0.2
Autumn	**Landward**	6528046	3264	1920	**1.9**
	Seaward	3104380	1552	913	0.9
Annual	**Landward**	55952619	27976	16456	**16.5**
	Seaward	22428790	11214	6596	6.6
Annual	**Toward ancient constructions**	38030129	19015	11185	**11.2**
	Seaward from ancient constructions	5456841	2728	1605	1.6

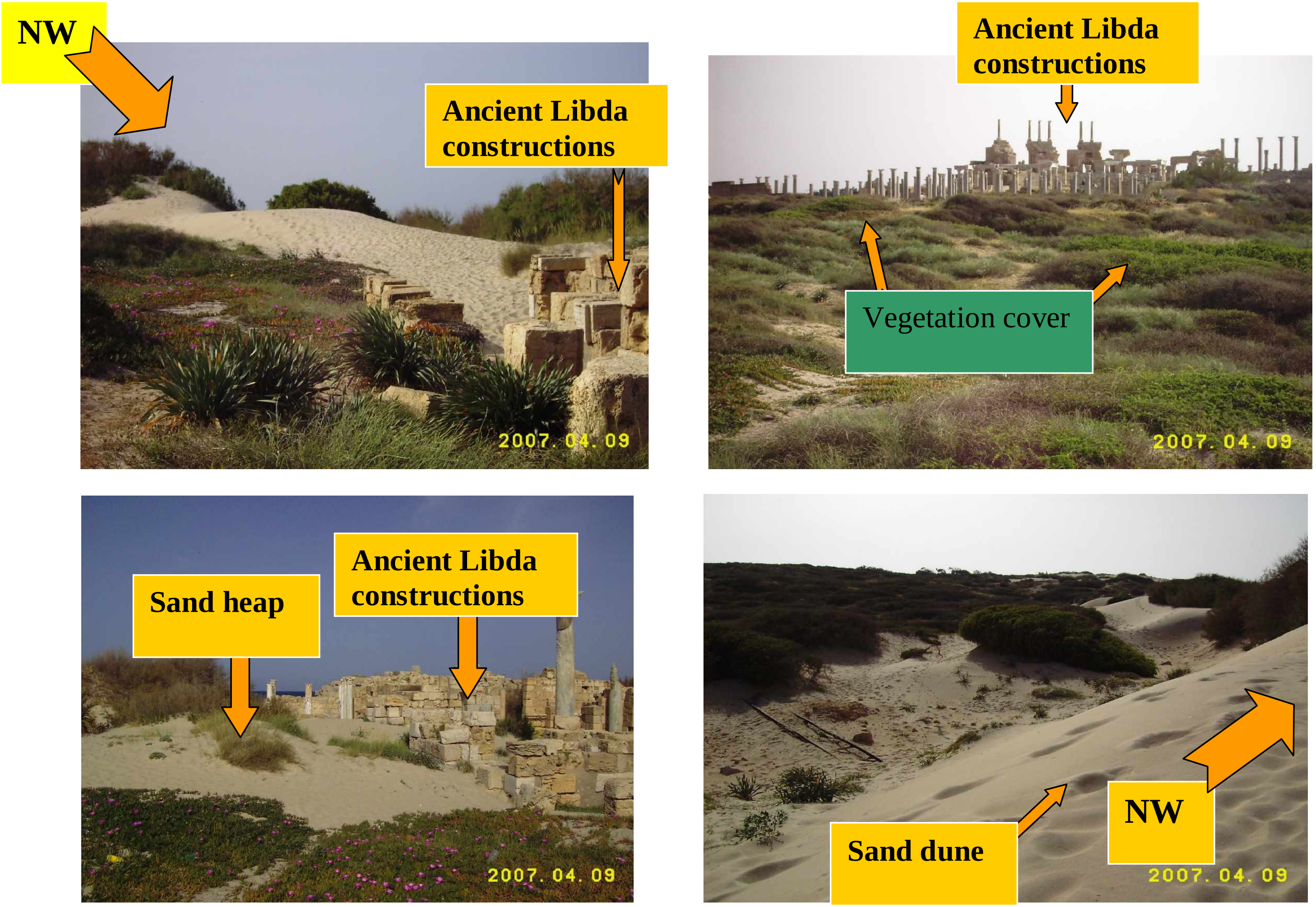

Fig. (5): Vegetation cover anchored the soil and hold its particles down.

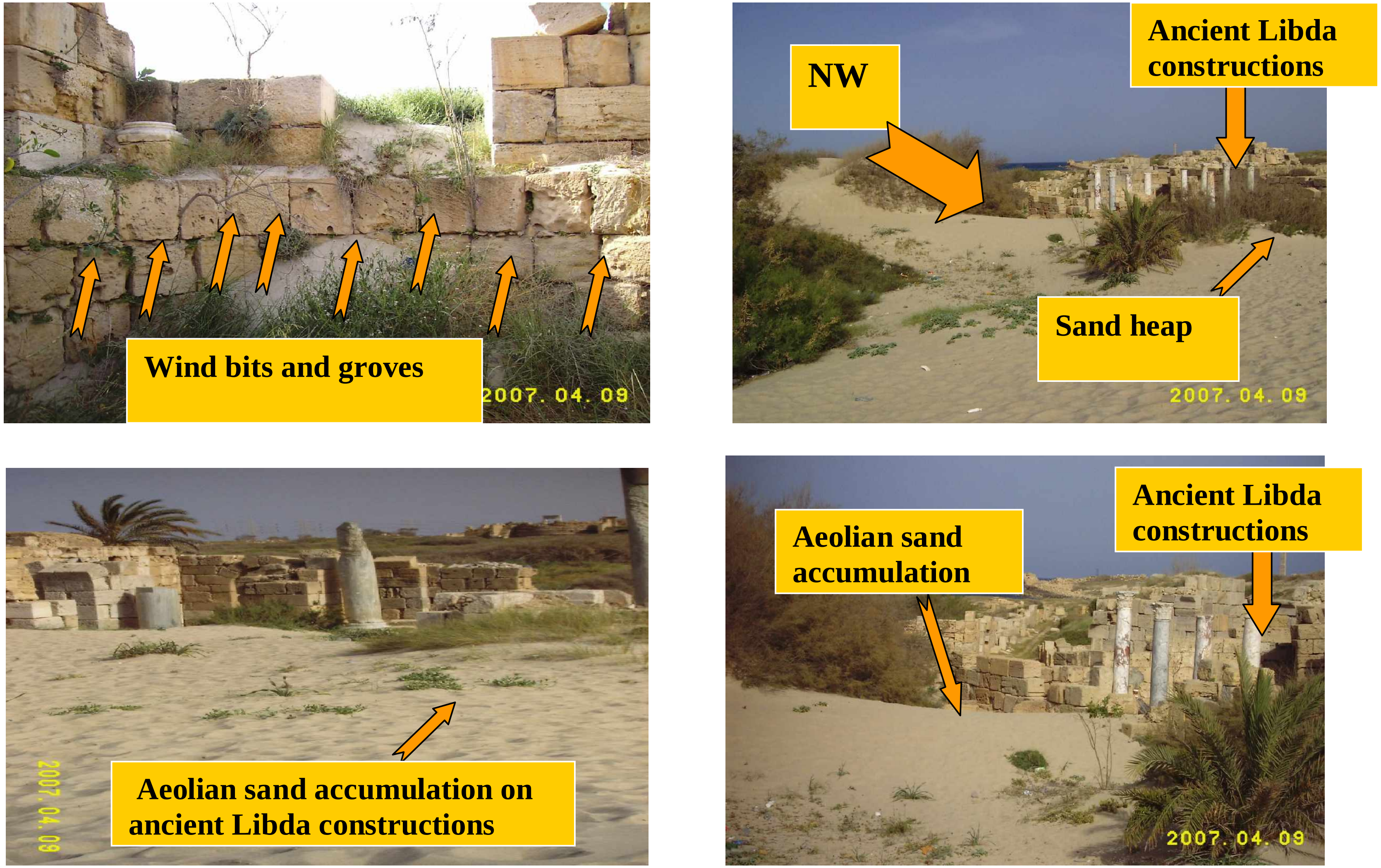

Fig. (6): Sever impact on the ancient constructions behind the western sandy beach. Note, the little vegetation cover.