trend of the SBS index, calculated for both SBS-modified bitumens, using Equation 3, and plotted in Figure 7c. As is well known, although oxidation does not affect the phenyl rings, but only the butadiene units, the SBS index can be considered to investigate SBS degradation, and again B2_HSBS proves more stable than B2_LSBS.

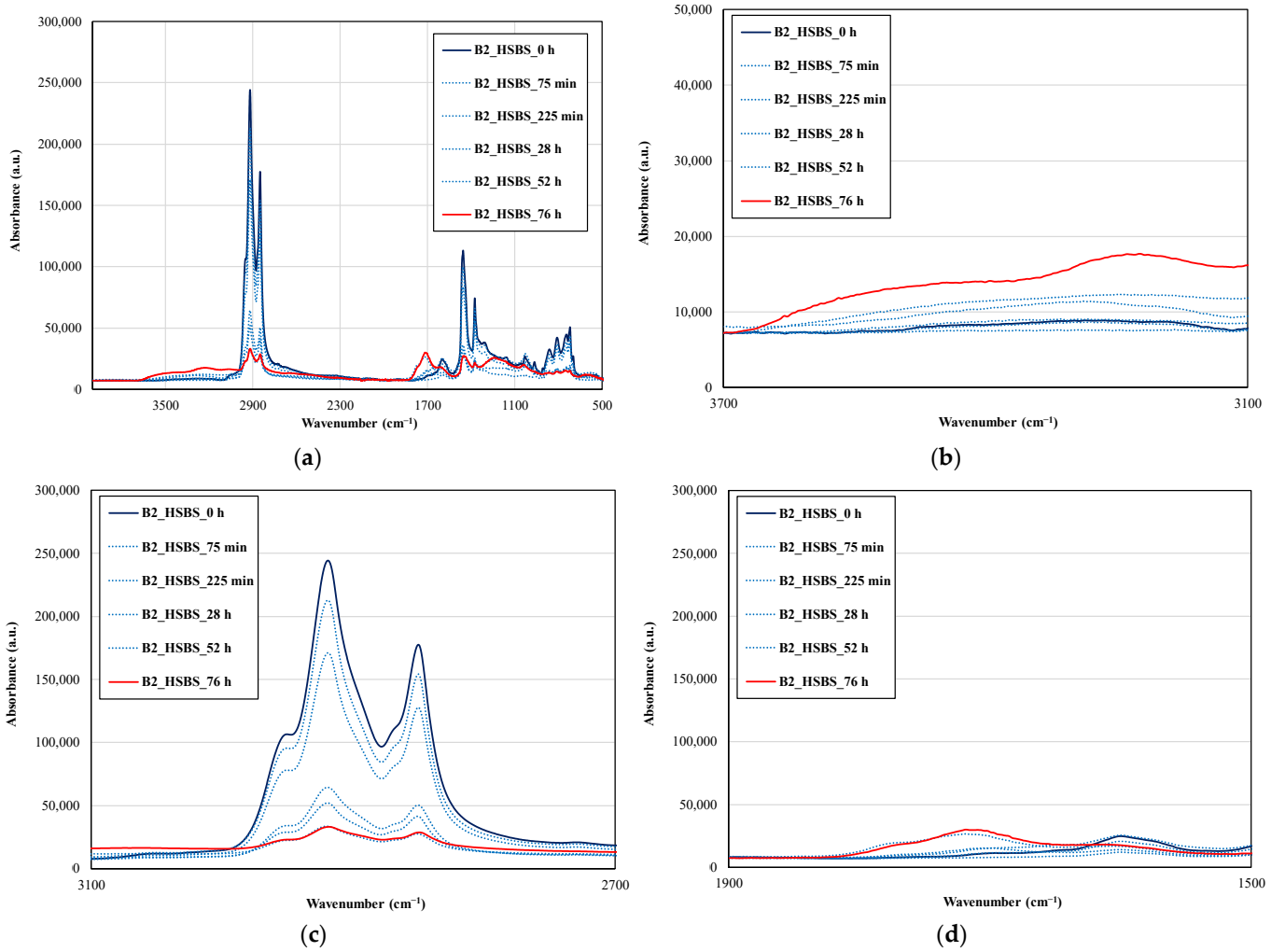


Figure 6. ATR-FTIR spectra of B2_HSBS at different UV irradiation times: (**a**) whole spectra, (**b**) hydroxyl range, (**c**) CH stretching range and (**d**) carbonyl range.

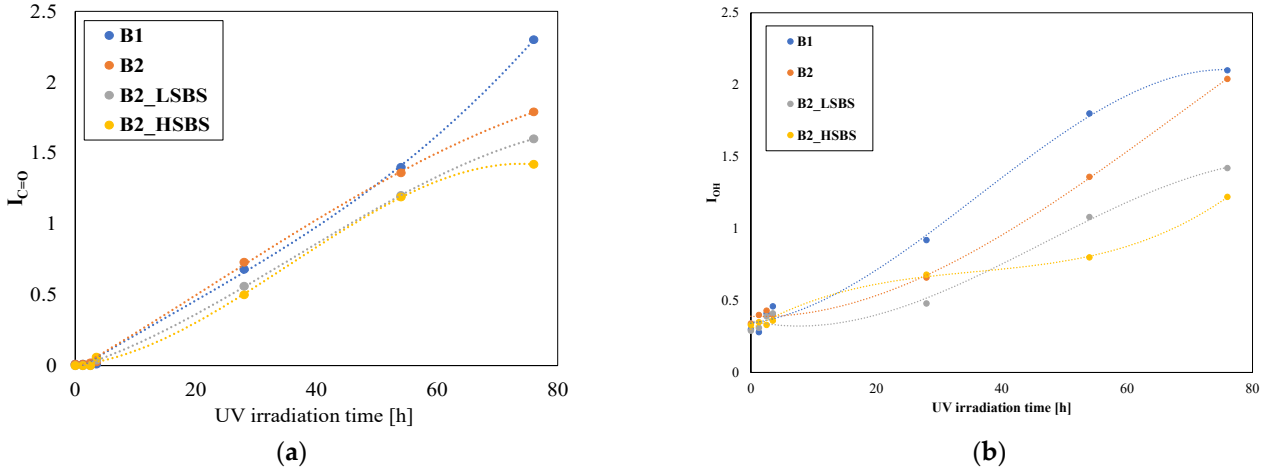
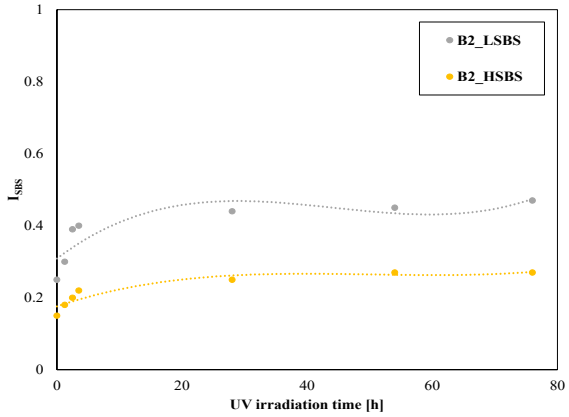
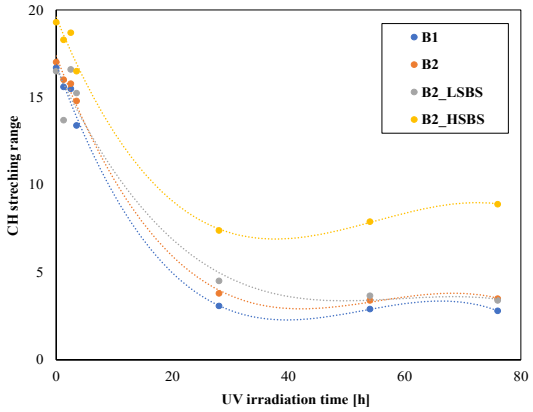


Figure 7. *Cont.*



(**c**)



(**d**)

Figure 7. Peak analysis: (**a**) $I_{C=O}$ (Equation (1)); (**b**) I_{OH} (Equation (2)); (**c**) I_{SBS} (Equation (3)); (**d**) CH stretching range variations, as a function of UV irradiation times.

Table 3. Peak assignment of bitumen, according to the literature [26–28].

Wavenumber (cm^{-1})	Peak Assignment
2924, 2852	Asymmetric and symmetrical stretching vibration of C-H in methylene
2729	Stretching vibration of aldehyde group
1695	C=O stretching vibration
1671	C=O stretching vibration of primary amide carbonyl
1454	Scissor vibration of methylene (—CH2—)
1376	Umbrella vibration of methyl (—CH3—)
1021	Stretching vibration of sulfoxide group (S=O)
810, 860	Stretching vibration of benzene ring
743	Bending vibration of aromatic branched chain
723	Synergistic vibration of methylene segment $(CH_2)_n$ ($n \geq 4$)

Therefore, in Figure 7d, the overall trends related to the variations of the CH stretching vibration range for all the investigated bitumens are plotted. Considering that the decrease of these peaks could be related to reductions of CH vibrations, i.e., mobility due to crosslinking formations and/or bitumen hardening, it is clearly noticeable that both SBS-modified bitumens are more stable than the neat bitumen, and again the best result is obtained for bitumen containing a high SBS amount, i.e., B2_HSBS, which shows the lowest variation in the CH range.

To sum up, the spectroscopy analysis of UVB irradiated bitumens confirms that the high penetration grade bitumen is more stable against UVB ageing, and again, the presence of SBS makes the bitumens less likely to oxidize, especially, if SBS is added at a high amount.

4. Conclusions

In this work, the effect of short-term and UV irradiation on the performance of two neat bitumens (low and high penetration grade samples, very commonly used in Italy) and two SBS-modified bitumens (low and high SBS content) was investigated. The effect of the SBS-modifier amount on short-term and UVB ageing behaviour of bitumens was examined and discussed. Short-time ageing behaviour was investigated by performing the rolling thin film oven test (RTFOT), while artificial UV ageing was investigated using UVB lamps and monitoring the structural changes at different exposure times.

The results obtained suggest that higher penetration grade bitumen is more thermally stable than bitumen with a lower penetration grade, and besides, the presence of the SBS has a very noticeable beneficial effect on bitumen stability. Further, to simulate bitumen service life, all samples were subjected to UVB irradiation, and their structural changes were

monitored through spectroscopy surface analysis (ATR-FTIR). The increase of carbonyl and hydroxyl functions suggests the formation of a large content of oxygen-containing groups, which highlights the degradation undergone upon UV irradiation. The decrease of CH starching vibrations suggests the occurrence of crosslinking, and subsequent, sample hardening. In these conditions too, high penetration grade bitumen proves more stable and less likely to form oxygen-containing groups than low penetration grade bitumen. Therefore, the presence of SBS in bitumen, especially at a high amount, has a beneficial effect on the oxidative resistance of bitumen, making bitumen more stable even with UV irradiation.

Summarizing, all the results obtained highlight that the high penetration bitumen is more stable in both production and UVB ageing conditions, and the presence of SBS has a beneficial effect on the ageing resistance of bitumens, that is even more evident if SBS is added at a high amount. Indeed, further investigations are needed to evaluate the ageing behaviour of the modified binders: in particular, future analyses will have to involve base bitumen from different sources, as well as different modifiers, that is both virgin and recycled polymers.

Author Contributions: Conceptualization, C.C., R.T. and N.T.D.; methodology, C.C., R.T. and N.T.D.; investigation, C.C., R.T. and N.T.D.; writing—original draft preparation, C.C., R.T. and N.T.D.; writing—review and editing, C.C., R.T. and N.T.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research was financially supported by both the Italian Ministry of University and Research with the research grant PRIN 2017 USR342 Urban Safety, Sustainability and Resilience and the ERDF Regional Operational Programme Sicily 2014–2020 (POR FESR Sicilia 2014–2020), Action 1.1.5 "SMARTEP".

Conflicts of Interest: The authors declare no conflict of interest.

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