Original Research Article

Properties of Boards Prepared from Mixture of Mineral Adducts with Bark and Cone of Calabrian Pine (*Pinus brutia*)

ABSTRACT

Red pine cone and bark chips were used for experimental boards manufacturing with various propertions of mineral olivine and dolomite in the presence of urea-formaldyhde adhesive. Olivine and dolomite addition with some of the formulations clearly retarded the water sorption change in both bark (Type 1 boards) and cone (Type 2 boards) based experimental panels. However, the lowest water sorption value of 15.20% was found in dolomite contain (40% dolomite 60% bark chip, w/w) sample which show approximately 169.6% lower than olivine contain sample at similar proportions. However, it is important to note that Type 1 boards show considerably lower water sorption than Type 2 boards at similar experimental conditions. The boards which produced with 10-, 20-, and 30% dolomite and 90-, 80-, 70% bark chips (XB_I, XB_{II} and XB_{III}) proportions, show higher Thickness swelling than control (B_0) while rest of both type boards show lower thickness swelling than control samples, regardless of type of mineral or experimental conditions. The highest thickness swelling difference (improvement) of-79.1% was found with sample of YB_V which produced with equally (1:1, w/w) proportions olivine and pine cone chips in matrix. It is noticeable that dolomite addition to Type 1 boards are usually effects higher IB values than olivine added samples while the highest IB value of 0.72 MPa was found with sample of XB_V. Moreover only sample of XB_{II} (20% dolomite and 80% pine bark chip in boards propertions, w/w) show higher MOR strength value (3.26 MPa) than control (B_0: 3.63 MPa), regardless of mineral proportions. In Type 2 boards, all experimental panels that prepared with two mineral addition at five loading level show lower MOR values than control (C_0: 6.59 Mpa). It is also realized that both Type 1 and 2 type experimental panels show lower elastic property (MOE) than control samples (B_0: 1129.3 MPa: C_0: 820.1).

Keywords: Dolomite, olivine, red pine bark, red pine cone, mechanical properties, biocomposites

1. INTRODUCTION

In these days, requisition for natural materials in composite production has been incrementing incredibly due to urbanization and expeditious industrial development. However, bio-composites have conventionally been achieved by mixing bio-based raw materials with various synthetic binders. Some common of those are the primary structural developing material, consists of particleboard, fiberboard and plywood in different proportions as per design strength requirement [1-2]. Despite many advantages of those materials, there is also some important drawback which are low fire, heat-, and moisture resistance [1-5]. In these respects, environmentally friendly bio-composite manufacturing has long been employed to alter undesirable lignocellulosic properties [4-5]. Nevertheless, the use of synthetic additives has major downsides, specifically the adverse environmental impacts associated with their production, their relatively high cost, and huge energy consumption during their production. In recent years sizably voluminous greenhouse gas emission (mainly CO_2) and high energy required in the production of wood products, causing a severe difficulty on ecology [6]. Considering the negative impacts of using petroleum-based additives (i.e hydrophobic substances, reinforced elements), industries and researchers are seeking alternative cost-effective, and durable elements to replace or minimize the use of traditional additives in composite manufacturing process [7-8]. The most appropriate way to overcome the environmental impact is the effective utilization of alternative additives or lignocellulosic waste materials in matrix structure. The benefits of such materials in composite are documented by various researchers [9-11]. In recent studies, unconventional wastes such as forest residues of bark and cones have been utilized in greener material production [12-13]. Several literature interpretations reported the potential of pine cone and bark as tree residue using in composite and paper making [12-14]. However, there has been an increasing interest in the use of non-traditional additives to improve the engineering properties of bio-composites. As a result, a variety of novel or improved sustainable materials has been proposed and well documented in the literature. Among the diverse these additives, minerals, including cement, gypsum and magnesia have been investigated for their utilization in various type material manufacturing experiences [15-17]. It has been proposed that some minerals are capable of forming stable structures with strength improvement properties after reacting with the wood in the presence of water. Dolomite is a mineral formed by the combination of calcium (Ca) and magnesium (Mg) in limestone ($CaCO_3.MgCO_3$) [5]. It is mostly utilized for production of iron- steel, ceramics, paints, fertilizer, glass, cement and bricks [5]. Olivine is classified as a rock-forming mineral. Its chemical formula is (Mg2+, Fe2+).2SiO_4 and usually found in crystal aggregates [5]. The various literature studies revealed that the utilization of dolomite as a binder and granular material (fine and coarse) in cement concrete and other applications influences their property. Various studies already exist on the utilization of dolomite- and olivine waste as material substitute in metallurgy and construction industry [5, 17-20].

Although there is some literature reports that improve many properties of lignocellulosic matter when used in composite matrix together. But there are very limited studies on the use of olivine and dolomite in the forest products industry. However, limited to no study has been undertaken to evaluate the effect of non-traditional additives such as; olivine and dolomite and their combination with mixing lignocellulosic in bio-composite manufacturing [18-20]. The high resistance properties of olivine and dolomite against abrasion and fire could be a potential material for bio-composite manufacturing. Therefore, the objective of this study was to examine selected physical performances of experimental panels manufactured from olivine and dolomite mixed with pine tree residues of cone and bark particles.

2. MATERIALS AND METHODS

Calabrian pine tree (*Pinus brutia* Ten.) residues of bark and cones were obtained from Isparta region in Turkey. The pine cone and barks were turned to chips at laboratory type hammer mill. The chips were screened to 1-3 cm particles and dried in the oven at 105 (± 3 ^{o}C) until they reached 2-3% moisture content. The bonding agent employed was urea-formaldehyde resin supplied by a commercial operated particleboard plant, in Turkey. It has 65% solid content and 20% ammonium chloride hardener, utulized as received. The glue was applied 10% and hardener was 1% in the test boards by weight based on oven dry material. The minerals of olivine and dolomite were received from a company that operated in Isparta-Aksu mining site, in Turkey. Metal mold plates with the dimensions of 400 x 400 x 10 mm was used to prepare the board paste. Then it were pressed for 5 minutes under 2.5 N/mm^2 at 170-180 ºC with laboratory type electrically heated press. Boards were kept between metal plates after the end of pressing process and then climatized. The experimental panels were conditioned at 23 ºC and 65% relative humidity and samples were cut to determine the IB (Internal Bond), MOE and MOR (Modulus of Elasticity and Rupture), TS (Thickness Swelling after two- and 24-hours' immersion in water) and The Water Absorption (WA, %), in accordance with TS EN 310 (1999), TS EN 319 (1999) and TS EN 317 (1999), ASTM D 1037, standards, respectively. Some code number and abbreviations were established throughout the study, the code number established for experimental boards are given in Table1.

Table 1. Content proportions and given code number of experimental boards

	Mineral ratio (w, %)	**Lignocellulosic ratio (w, %)**

Board codes		Dolomite (X)	Olivine (Y)	Bark chips (B)	Cone chips (C)
B_0	**C_0**	0	0	100	100
XB_I-YB_I	**XC_I-YC_I**	10	10	90	90
XB_{II}-YB_{II}	**XC_{II}-YC_{II}**	20	20	80	80
XB_{III}-YB_{III}	**XC_{III}-YC_{III}**	30	30	70	70
XB_{IV}-YB_{IV}	**XC_{IV}-YC_{IV}**	40	40	60	60
XB_V-YB_V	**XC_V-YC_V**	50	50	50	50

3. RESULT AND DISCUSSION

Water absorption and thickness swelling tests are popular tests for evaluating the durability through water transportation mechanisms via pores in composites. Tables 1 summarize water absorption (WA, %) properties of boards produced by adding various proportions of dolomite and olivine to red pine bark- and cone chips in composite structure. Data of WA (%) in Table 2 show that olivine and dolomite addition with some of the formulations clearly retarded the sorption change in both bark and cone based experimental panels. It can be seen that olivine is proved to be considerably more effective in reducing the water sorption with samples of YB_{I-III} and YC_{I-II} while dolomite show lowering sorption properties in samples of XB_{IV-V} and XC_{III-V}, at similar experimental conditions. However, the lowest sorption value of 15.20% was found with sample of XB_{IV} which indicates approximately 169.6% lower sorption value than counterpart sample of YB_{IV}. It is also notable that bark type boards show considerably lower water sorption than cone type boards at similar experimental conditions. This is probably due to higher flexibility and more easy arrangement of bark chips rather than cone chips when mixed with minerals in network matrix structure.

Table 2. The water sorption (%) properties of experimental boards.

Boards	X	Y	Δ from X-Y (%)
Mineral- pine bark based panels			
B_0	36.73	36.73	0
XB_I-YB_I	30.58	19.33	36.8 (-Y)
XB_{II}-YB_{II}	40.49	25.16	37.8 (-Y)
XB_{III}-YB_{III}	49.74	27.70	44.3 (-Y)
XB_{IV}-YB_{IV}	15.20	40.98	169.6 (-X)
XB_V-YB_V	25.83	32.25	24.9 (-X)
Mineral-pine cone based panels			
C_0	53.68	53.68	0
XC_I-YC_I	60.29	59.04	2.1 (-Y)
XC_{II}-YC_{II}	62.55	48.58	22.3 (-Y)
XC_{III}-YC_{III}	46.18	75.39	63.3 (-X)
XC_{IV}-YC_{IV}	36.37	37.89	4.1 (-X)
XC_V-YC_V	30.69	59.19	92.9 (-X)

Figure 1 depicts the water absorption (WA, %) differences (%) of boards from controls (B0-C0), produced by adding various proportions of dolomite and olivine to pine bark- and cone chips in composite structure. In general, for bark-type experimental panels, it can be seen that samples of XB_{II}, XB_{III} and YB_{IV} show 10.3%, 35.4% and 11.5% higher WA properties than controls while others show in range of -58.7% (XBI_V) to –12.2% (YB_V) lower WA properties than control samples. For cone-type boards, samples of XC_I, YC_I, XC_{II}, YC_{III} and YC_V samples show 12.3%, 9.9% and 16.5%, 40.4% and 10.2% higher WA properties than controls while others show in range of -542.8% (XC_V) to –9.5% (YC_{II}) lower WA properties than control samples. Although it is not easy to correlate WA properties of boards with panel mixture proportions, but there is considerably lowering WA properties observed at certain conditions.

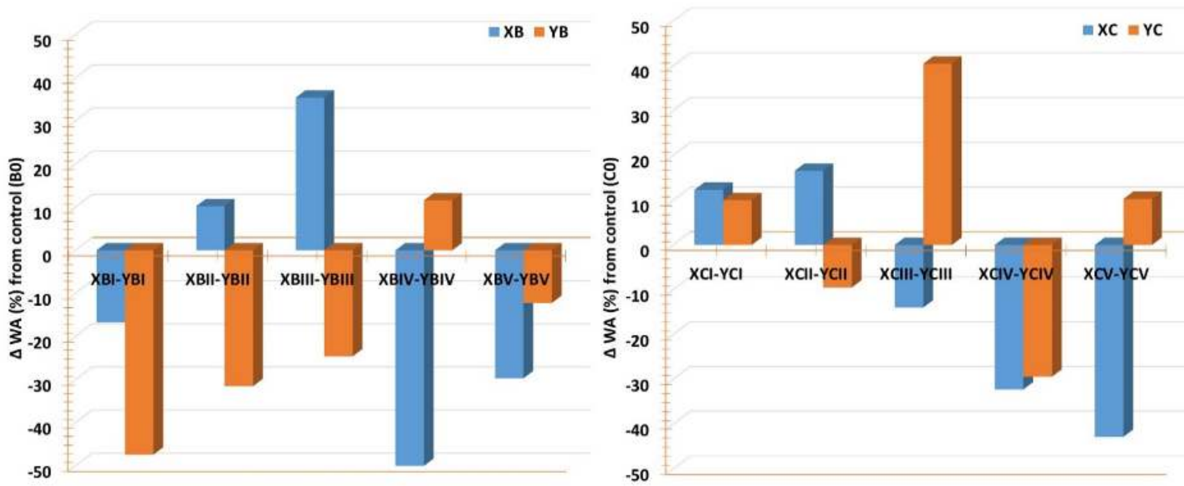

Figure 1. Water absorption (Δ%) difference properties of experimental boards from controls

Table 3 shows the comparative thickness swelling (%) properties of boards after 24 h. immersion in water. It is also noticeable that samples of $XB_{I\text{-}III}$ show higher thickness swelling values than control sample (B_0: 11.73%), all other panels show lower TS properties than controls, regardless of experimental conditions or preparation formulations. However, except sample of XB_{IV} which show approximately 59.9% lower TS than counterpart olivine added samples (YB_{IV}), in all other conditions, olivine added samples show in range of 1.3% (YC_{II}) to 73.9% (YC_I) lower TS than dolomite added at similar experimental conditions. This is probably due to higher compability of olivine with both pine bark- and cone in matrix structure.

Table 3. The thickness swelling (%) properties of experimental boards.

Boards	**X**	**Y**	**Δ from X-Y (%)**
Mineral- pine bark based panels			
B_0	11.73	11.73	0
XB_I-YB_I	12.94	6.47	50 (-Y)
XB_{II}-YB_{II}	17.95	5.48	69.5 (-Y)
XB_{III}-YB_{III}	16.92	8.76	48.2 (-Y)
XB_{IV}-YB_{IV}	5.16	8.25	59.9 (-X)
XB_V-YB_V	6.79	2.46	63.8 (-Y)
Mineral-pine cone based panels			
C_0	21.44	21.44	0
XC_I-YC_I	20.15	5.25	73.9 (-Y)
XC_{II}-YC_{II}	15.93	15.73	1.3 (-Y)
XC_{III}-YC_{III}	13.51	8.24	39.1 (-Y)
XC_{IV}-YC_{IV}	16.61	12.55	24.4 (-Y)
XC_V-YC_V	13.66	6.06	55.6 (-Y)

Figure 2 shows the thickness swelling differences (Δ%) of boards from controls (B_0-C_0), made by adding various proportions of dolomite and olivine to red pine bark- and cone chips in composite structure. However, except samples of $XB_{I\text{-}III}$ which show higher TS than control (B_0), all other bark-and cone type boards show lower thickness swelling than control samples, regardless of type of mineral additive or proportion in panel structure. The highest thickness swelling difference (improvement) of -79.1% was found with sample of YB_V, followed by samples of YC_I (-75.5%) and YC_V (-71.7%). It is notable that except sample of XB_{IV} which show higher swelling retardancy than counterpart sample of YB_{IV} (-56.1% vs -29.7%), olivine addition in to all bark- and cone type panels show lower TS property under similar additive proportions and manufacturing conditions than dolomite added samples. It is clear that the marked effect of lowering TS with both mineral addition to cone and bark type boards which is noticeable as shown in Table 2 and Figure 2.

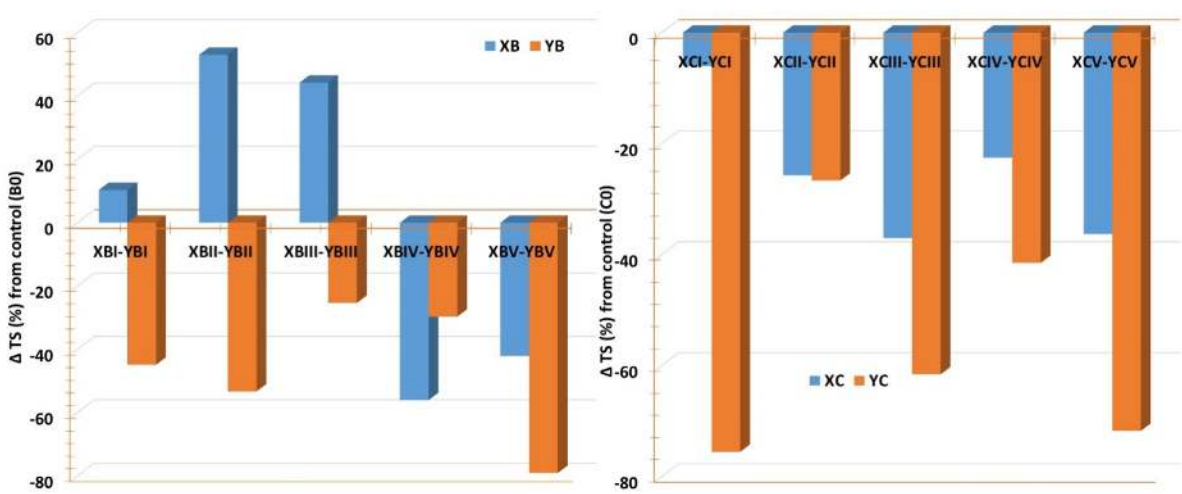
XB
YB
60
40
20
0
-20
-40
-60
-80
Δ TS (%) from control (B0)
XBI-YBI
XBII-YBII
XBIII-YBIII
XBIV-YBIV
XBV-YBV
0
-20
-40
-60
-80
Δ TS (%) from control (C0)
XCI-YCI
XCII-YCII
XCIII-YCIII
XCIV-YCIV
XCV-YCV
XC
YC

Figure 2. Thickness swelling (Δ%) difference properties of experimental boards from controls

Average values of IB, MOR, and MOE values obtained from two type experimental panels which produced with various proportions with mineral additives are summarized in Table 4. As it seen in Table 4, pine cone control panel show higher IB (B_0: 0.36 MPa, C_0: 0.90 MPa) and MOR strength properties (B_0: 3.63 MPa, C_0: 6.59 MPa) while control bark panel's MOE value is higher (B_0: 1129.3, C_0: 820.1 MPa).
For bark type boards, dolomite addition is usually affecting higher IB values than olivine added samples while the highest IB value of 0.72 MPa was found with sample of XB_V. However, there is not a clear correlation was found between mineral type of proportions for MOR and MOE properties. The highest MOR value of 3.26 MPa was found with sample XB_{II} which is approximately 59.2% higher than counterpart olivine added sample (YB_II: 1.33 MPa). It is also noticeable that only sample of XB_{II} show higher MOR value than control (B_0: 3.63 MPa), regardless of mineral proportions. All mineral added bark type boards show lower MOE values than control sample (B_0: 1129.3 MPa). The olivine added samples of YB_I and YB_{II} show %9.5 and 60.1% higher MOE values than counterpart dolomite added samples, respectively. However, increasing dolomite content in bark-based panels (XB_{III}- XB_V) show higher MOE values than olivine samples which prepared similar conditions.

For cone type boards, only samples of XC_{II}, YC_{II} and YC_{III} show higher IB properties than control sample (C_0: 0.90 MPa). The highest IB value of 1.32 was found with sample YC_{II}, followed by YC_{III} (1.10 MPa) and XC_{II} (0.97 MPa) in that order. It is notable that olivine is more effective for higher IB property of experimental board up to 30% (w/w, %) addition level (YC_I-YC_{III}) while dolomite is more effective in 40 and 50% addition level in panel formulations (XC_{IV} and XC_V). However, all experimental panels that prepared with two mineral addition at five loading level show lower MOR values than control (C_0: 6.59), regardless of experimental conditions. The lowest MOR value of 1.90 MPa was found with sample of XC_{IV}. Similar trend was also found for MOE values that all experimental panels which prepared with mineral additions show lower MOE than control (C_0: 820.1 MPa). It is also notable that except sample of YC_V which prepared with 1:1 olivine/pine cone chip mixture, all other boards which prepared with dolomite show higher MOE properties than olivine added samples at similar conditions.

Table 4. The mechanical strength properties of experimental boards.

Samples	IB (MPa)			MOR (MPa)			MOE (MPa)		
	X	Y	Δ from X-Y (%)	X	Y	Δ from X-Y (%)	X	Y	Δ from X-Y (%)
Mineral-red pine bark-based panels									
B_0	0.39	0.39	0	3.63	3.63	**0**	1129.3	1129.3	0
XB_I-YB_I	0.50	0.32	36 (+X)	4.42	2.29	**48.2 (+X)**	740.3	810.7	9.5 (+Y)
XB_{II}-YB_{II}	0.58	0.49	15.5 (+X)	2.37	2.39	**0.8 (+Y)**	449.4	719.4	60.1 (+Y)
XB_{III}-YB_{III}	0.57	0.29	49.1 (+X)	3.26	1.33	**59.2 (+X)**	609.4	458.6	24.7 (+X)
XB_{IV}-YB_{IV}	0.59	0.26	55.9 (+X)	1.76	1.19	**32.3 (+X)**	812.6	704.1	13.4 (+X)
XB_V-YB_V	0.72	0.38	47.2 (+X)	1.23	1.37	**11.4 (+Y)**	503.1	417.1	17.1 (+X)
Mineral-red pine cone-based panels									
C_0	0.90	0.90	0	6.59	6.59	0	820.1	820.1	0
XC_I-YC_I	0.84	0.89	5.9 (+Y)	4.94	3.51	28.9 (+X)	601.7	519.6	13.6 (+X)
XC_{II}-YC_{II}	0.97	1.32	36.1 (+Y)	3.76	4.0	6.4 (+Y)	525.1	457.8	12.8 (+X)
XC_{III}-YC_{III}	0.72	1.10	52.8 (+Y)	1.92	2.04	6.3 (+Y)	471.1	614.9	30.5 (+Y)

XC_{IV}-YC_{IV}	0.87	0.74	14.9 (+X)	1.90	2.55	32.8 (+Y)	623.9	540.1	13.4 (+X)
XC_{V}-YC_{V}	0.70	0.69	1.4 (+X)	2.27	1.13	50.2 (+X)	603.6	634.6	5.1 (+Y)

Figure 3 shows the Internal Bond (IB) strength differences (Δ%) of boards from controls (B_0 and C_0), made by adding various proportions of dolomite and olivine to red pine bark- and cone chips in composite structure. However, except samples of YB_I, YB_{II} and YB_{IV} which show -17.9%, -25.6% and -2.6% lower than control bark type board (B0: 0.39 MPa), all other bark type boards show higher IB values than control sample. The highest IB difference (improvement) of 84.61% was found with sample of XB_V, followed by samples of XB_{IV} (51.3%) and XBII (48.7%). It is clear that all dolomite addition in to all bark type panels show higher IB property under similar manufacturing conditions than olivine added bark samples. It is clear that the marked effect of increasing IB with dolomite addition to bark type boards which is noticeable as shown in Table 4 and Figure 3. It is noticeable that only cone type boards of XC_{II}, YC_{II} and YC_{III} show higher IB values than control (C_0: 3.63 MPa).

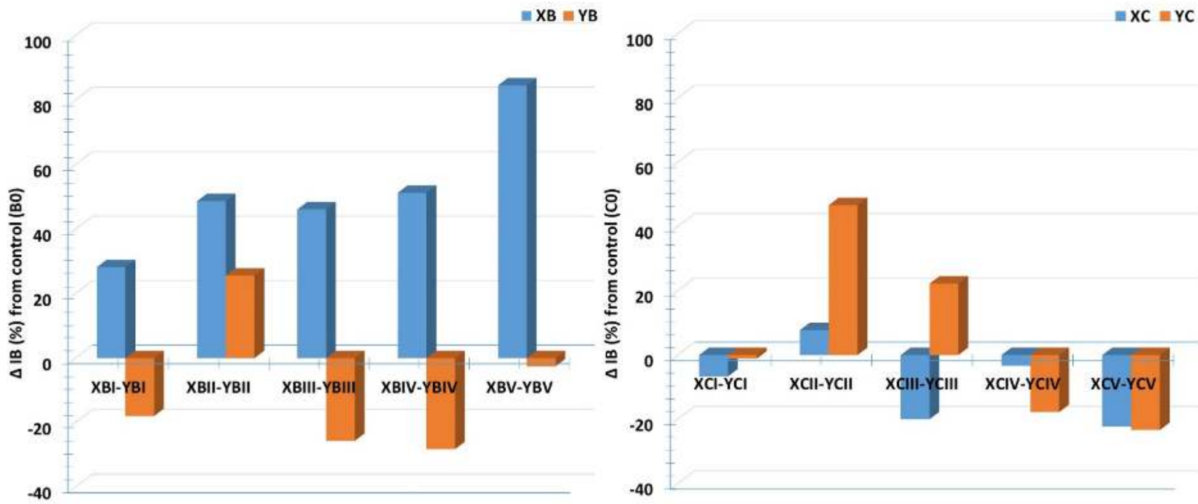

Figure 3. IB strength (Δ%) difference properties of experimental boards from controls

The bending strength (MOR) differences (Δ%) of boards from controls (B_0 and C_0), made by adding various proportions of dolomite and olivine to red pine bark- and cone type boards re shown in Figure 4. In general, except sample of XBI which show only 21.8% higher MOR value than control (B0), rest of experimental panels show lower MOR values than control samples (B_0: 3.63 MPa, C_0: 6.59 MPa), regardless of panel type and mineral additive proportions. The highest MOR reduction (-67.2%) was found for YBIV sample in bark type boards and YC_{III} (-70.9%) in cone type boards. It could be concluded that the addition of both mineral in top in cone bark- and cone type boards are not improving effects on MOR strength properties.

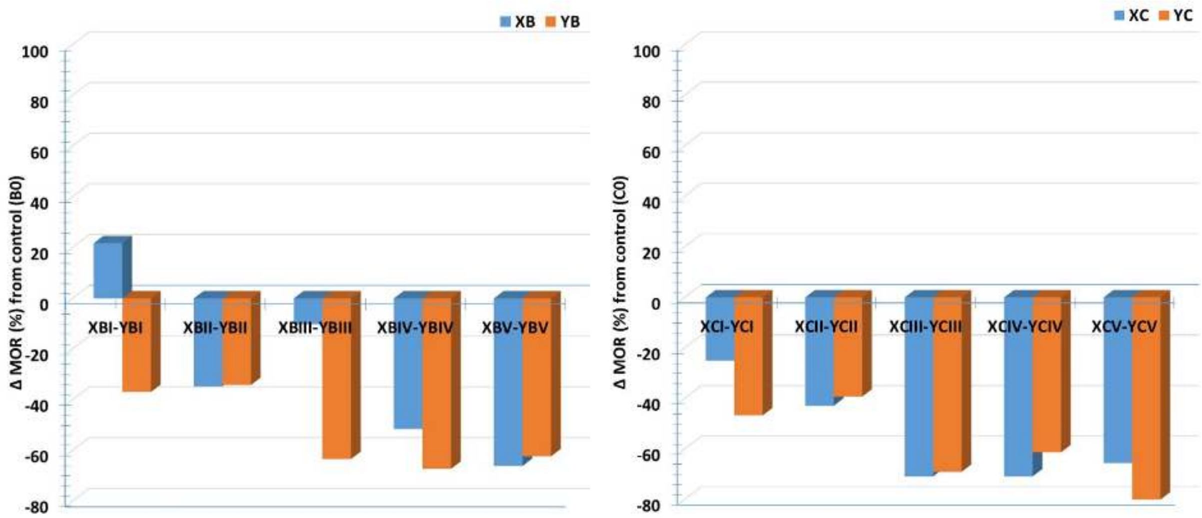

Figure 4. MOR strength (Δ%) difference properties of experimental boards from controls

The elasticity (MOE) property changes (Δ%) of boards from controls (B_0 and C0), made by adding various proportions of dolomite and olivine to red pine bark- and cone type boards re shown in Figure 5. It can be clearly seen that all the experimental panels show lower elasticity properties than control samples (B_0: 1129.3 MPa: C_0: 820.1), regardless of panel type and experimental conditions. The highest MOE reduction (-63.1%) was found for YB_V sample in bark type boards and YC_{II} (-44.2%) in cone type boards. It could be expected considering more rigid mineral addition to cone bark- and cone type boards structures. But there is not any clear correlation was found between type of mineral additives and lignocellulosic type (cone or bark). It is also important to note that the modulus of elastic values was calculated lower than the standard value for all boards that red pine bark/cone chips and dolomite/olivine mixture, including the control samples.

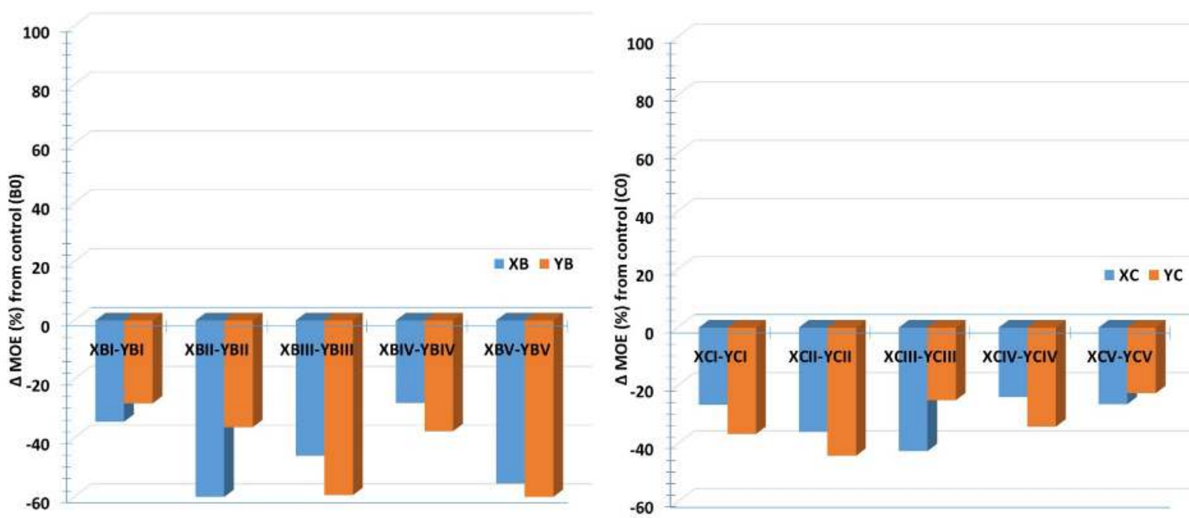

Figure 5. MOE (Δ%) difference properties of experimental boards from controls

4. CONCLUSION

Since the polymerization degree and crystalline region ratio of cellulose is less than wood cellulose in the structure of red pine bark, it can be said that bark cellulose is more accessible than other wood cellulose. This situation enables surface photochemical reactions to occur more easily under external atmospheric conditions. The results obtained from samples with olivine confirm this information. Despite the internal bond strength properties were found higher than the standard value for all board types, the mineral addition to the mixture decrease the bending strength properties of the boards. Similarly, the modulus of elastic values was affected negatively by addition of olivine and dolomite minerals. However, the contribution of olivine and dolomite addition to the wood-bark mixture/wood-cone mixture was provided the insulation as 27.19% in terms of the thermal insulation. It can be concluded that the olivine and dolomite addition reduce the degree of combustion on the surface flammability limit of the material.

REFERENCES

1. Maloney, T.M. (1996). The family of wood composite materials, *Forest Products Journal*, 46 (2), 19-26.
2. Forest Products Laboratory (2010). Wood Handbook-Wood as an engineering material*, General Technical Report FPL-GTR-190,* Madison, WI, 508p.
3. McKeever, D. B. (1997). Engineered wood products: a response to the changing timber resource. *Pacific Rim Wood Market Report*, *123*(5), 15.
4. Sahin, H. T., Simsek, Y. (2021). Mineral-Bonded Wood Composites: An Alternative Building Materials. In: *Engineered Wood Products for Construction*. IntechOpen. Pp.317-334
5. Yalcin, O.U. (2018). Investigation of performance properties of panels produced from some lignocellulosic sources with mineral (dolomite and olivine) additives, (Ph.D thesis; Turkish, abstract is in English), *Isparta University of Applied Sciences, the Institute for Graduate Education, Department of Forest Product Engineering*, Isparta-Turkey (169p.).
6. van Dam, J. E. (2008). Natural fibres and the environment: environmental benefits of natural fibre production and use. In: *Proceedings of the Symposium on Natural Fibres: Common fund for commodities, 20 October 2008, Rome, Italy,* (pp. 3-17).
7. Zhang, L. and Hu Y. 2014. Novel lignocellulosic hybrid particleboard composites made from rice straws and coir fibers. *Materials and Design,* 55:19-26.
8. Youngquist, J.A., Krzysik, A. M., Chow, P. and Meimban, R. (1997). Properties of composite panels. In: Paper and composites from Agro-based resources, R.M. Rowell, R.A. Young, J.K. Rowell, (Eds), *CRC Press Inc,* Boca Raton, Florida.
9. Rowell, R.M. (1997). Opportunities for composites fron Agro-based resources, In: Paper and composites from Agro-based resources, Rowell, R.M., Young, R.A.,Rowell, J.K., (Eds*), CRC Press Inc,* Boca Raton, Florida, 249-300 pp.
10. Ndazi, B., Tesha, J. V. and Bisanda E.T.N. (2006). Some opportunities and challenges of producing bio-composites from non-wood residues, *J. Mater Sci*., 41,6984–6990.
11. Rials, G. T. and Wolcott, M.P. (1997). Physical and mechanical properties of agro-based fibers, In: Paper and composites from agro based resources, Rowell, R.M., Young, R.A., Rowell, J.K. (Eds), *CRC Press Inc,* Boca Raton, Florida, 63-81 pp.
12. Sahin, H.T., Arslan, M.B. (2011). Weathering performance of particleboards manufactured from blends of forest residues with Red pine (Pinus brutia) wood, *Maderas: Ciencia y Technologia*, 13 (3), 337-346.
13. Yalçın, Ö. Ü., Şahin, H. T., & Kaya, A. İ. (2019). Investigation of some performance properties of panels produced from Red pine Bark and Cone sources with dolomite. *ICONST LST 2019*, 41.
14. Sahin, H. T., & Yalcin, O. U. (2017). Conifer Cones: An Alternative Raw Material for Industry. *Journal of Pharmaceutical Research International*, 1-9.
15. Aamr-Daya E, Langlet T, Benazzouk A & Quéneudec M (2008). Feasibility study of lightweight cement composite containing flax by-product particles: Physico-mechanical properties. *Cement Concrete Comp*. 30: 957–963.
16. Aggarwal LK, Agrawal SP, Thapliyal PC & Karade SR (2008). Cement-bonded composite boards with arhar stalks. *Cement Concrete Comp*. 30: 44–51.
17. Agrawal, Y., Gupta, T., Siddique, S., & Sharma, R. K. (2021). Potential of dolomite industrial waste as construction material: a review. *Innovative Infrastructure Solutions*, *6*(4), 1-15.
18. Emmanuel, E., Yong, L. L., Asadi, A. & Anggraini, V. (2020). Full-factorial two-level design in optimizing the contents of olivine and coir fiber for improving the strength property of a soft marine clay. *Journal of Natural Fibers*, 1-16.

19. Özdemir F (2016). Investigate on effect of dolomite mineral on some properties of high density fiberboard (HDF), (Turkish, Abstract in English) *Kahramanmaraş Sütçü İmam Üniversitesi Mühendislik Bilimleri Dergisi* 19, 93-98.2016.
20. Özdemir, F., Tutuş, A. & Çiçekler, M. (2016). Effect of Dolomite Mineral on Surface Roughness of High Density Fiberboard (HDF). In 2nd International Furniture Congress (pp. 498-501).
21. TS EN 310. (1999). Wood- Based panels- Determination of modulus of elasticity in bending and of bending strength,*TSE,* Ankara,.
22. TS EN 317. (1999). Particleboards and fibreboards- Determination of swelling in thickness after immersion in water, *TSE,* Ankara.
23. TS EN 319. (1999). Particleboards and fibreboards- Determination of tensile strength perpendicular to the plane of the board, *TSE,* Ankara,
24. ASTM 1037. Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials, ASTM International, West Conshohocken, PA, USA.