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ON bT-CLOSED SETS IN SUPRA TOPOLOGICAL SPACES

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ABSTRACT

In this paper, we introduce a new class of set namely bT^{μ} -closed sets in supra topological space. We further discuss the concept of bT^{μ}-continuity and obtained their applications.

***Keywords**: supra bT-closed and supra bT-continuity.*

1. INTRODUCTION

In 1983 Mashhour et al [2] introduced Supra topological spaces and studied S- continuous maps and S^{μ}-continuous maps. In 2010, Sayed *et al* [3] introduced and investigated several properties of supra b-open set and supra b-continuity. In 2011, Arockiarani and Trintia Pricilla [5] introduced and investigated several properties of a new type of sets called supra T-closed set and supra T-continuity maps. In this paper, we introduced the concept of bT^{μ} - closed sets and study its basic properties. Also, we introduce the concept of bT^{μ}- continuous functions and investigated several properties for these classes of functions in supra topological spaces.

2. PRELIMINARIES

Definition: 2.1[2, 3] A subfamily of μ of X is said to be a supra topology on X, if
(i) X, $\phi \in \mu$
(ii) if $A_i \in \mu$ for all $i \in J$ then $\cup A_i \in \mu$.

The pair (X, μ) is called supra topological space. The elements of μ are called supra open sets in (X, μ) and complement of a supra open set is called a supra closed set.

Definition: 2.2[3] (i) The supra closure of a set A is denoted by $cl^{\mu}(A)$ and is defined as $cl^{\mu}(A) = \cap\{B : B$ is a supra closed set and $A \subseteq B\}$.

(ii) The supra interior of a set A is denoted by $int^{\mu}(A)$ and defined as $int^{\mu}(A) = \cup\{B: B$ is a supra open set and $A \supseteq B\}$.

Definition: 2.3[2] Let (X, τ) be a topological spaces and μ be a supra topology on X. We call μ a supra topology associated with τ if $\tau \subset \mu$.

Definition: 2.4[3] Let (X, μ) be a supra topological space. A set A is called a supra b-open set if $A \subseteq cl^{\mu}(int^{\mu}(A)) \cup int^{\mu}(cl^{\mu}(A))$. The complement of a supra b-open set is called a supra b-closed set.

Definition: 2.5[6] Let (X,μ) be a supra topological space. A set A of X is called supra generalized b-closed set (simply $g^{\mu}b-$closed) if $bcl^{\mu}(A) \subseteq U$ whenever $A \subseteq U$ and U is supra open. The complement of supra generalized b-closed set is supra generalized b-open set.

Definition: 2.6[5] A subset A of (X, μ) is called T^{μ}-closed set if $bcl^{\mu}(A) \subseteq U$ whenever $A \subseteq U$ and U is $g^{\mu}b$ - open in (X,μ). The complement of T^{μ} - closed set is called T^{μ}-open set.

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Definition: 2.7[4] A subset A of a supra topological space (X, μ) is called supra regular open if A $=cl^{\mu}(int^{\mu}(A))$. The complement of supra regular open set is called supra regular closed set.

Definition: 2.8[4] A subset A of a supra topological space (X,μ) is called supra generalized b- regular closed set if $bcl^{\mu}(A) \subseteq U$ and whenever $A \subseteq U$ and U is supra regular open of (X,μ). The complement of supra generalized b- regular closed set is called supra generalized b- regular open set.

3. BASIC PROPERTIES OF bT^{μ}-CLOSED SETS

Definition: 3.1 A subset A of a supra topological space (X, μ) is called bT^{μ}-closed set if $bcl^{\mu}(A) \subseteq U$ whenever $A\subseteq U$ and U is T^{μ}- open in (X,μ).

The complement of supra bT^{μ}- closed set is called supra bT^{μ}-open set. We denote the family of all bT^{μ}- closed set by $bT^{\mu}(X, \mu)$.

Theorem: 3.2 Every supra closed set is bT^{μ}- closed.

Proof: Let $A \subseteq U$ and U is T^{μ}- open set. Since A is supra closed then $cl^{\mu}(A) = A \subseteq U$.We know that $bcl^{\mu}(A) \subseteq cl^{\mu}(A) \subseteq U$, implies $bcl^{\mu}(A) \subseteq U$. Therefore A is bT^{μ}- closed.

The converse of the above theorem need not be true as seen from the following example.

Example: 3.3 Let X= {a, b, c} and μ ={X, ϕ, {a}}.Then the set{a, c} is bT^{μ}- closed set in (X, μ) but not supra closed.

Theorem: 3.4 Every bT^{μ}- closed set is $g^{\mu}b$ - closed set.

Proof: Let $A \subseteq U$ and U is supra open set. We know that every supra open set is T^{μ}- open set, then U is T^{μ}-open set. Since A is bT^{μ} -closed set, we have $bcl^{\mu}(A) \subseteq U$. Therefore A is $g^{\mu}b$-closed set.

Example: 3.5 Let X= {a, b, c}. and μ = {X, ϕ, {a}}.Then the set{a, b} is $g^{\mu}b$- closed but not bT^{μ}- closed.

Theorem: 3.6 Every bT^{μ}- closed set is $g^{\mu}br$ - closed set.

Proof: Let $A \subseteq U$ and U is supra regular open set. We know that every supra regular open set is T^{μ}-open set, then U is T^{μ}-open set. Since A is bT^{μ} -closed set, we have $bcl^{\mu}(A) \subseteq U$. Therefore A is $g^{\mu}br$- closed set.

Example: 3.7 Let X= {a, b, c}. and μ = {X, ϕ , {a}}.Then the set{a, b} is g^{μ} br- closed set but not bT^{μ}- closed set.

Theorem: 3.8 The union of two bT^{μ}- closed set is bT^{μ}- closed set.

Proof: Let A and B two bT^{μ}- closed set. Let $A\cup B\subseteq G$, where G is T^{μ}- open.

Since A and B are bT^{μ} -closed sets. Therefore $bcl^{\mu}(A)\cup bcl^{\mu}(B)\subseteq G$. Thus $bcl^{\mu}(A\cup B)\subseteq G$. Hence $A\cup B$ is bT^{μ}-closed set.

Theorem 3.9 Let A be bT^{μ} -closed set of (X,μ). Then $bcl^{\mu}(A) - A$ does not contain any non empty T^{μ}-closed set.

Proof: Necessity Let A be bT^{μ}- closed set. suppose $F\neq \phi$ is a T^{μ}- closed set of $bcl^{\mu}(A) - A$. Then $F\subseteq bcl^{\mu}(A) - A$ implies $F\subseteq bcl^{\mu}(A)$ and A^{c}. This implies $A\subseteq F^{c}$. Since A is bT^{μ}- closed set, $bcl^{\mu}(A) \subseteq U^{c}$.Consequently, $F\subseteq [bcl^{\mu}(A)]^{c}$.Hence $F\subseteq bcl^{\mu}(A) \cap [bcl^{\mu}(A)]^{c} = \phi$. Therefore F is empty, a contradition.

Sufficiency: Suppose $A \subseteq U$ and that U is T^{μ} - open. If $bcl^{\mu}(A) \not\subset U$. Then $bcl^{\mu}(A) \cap U^{c}$ is a not empty T^{μ}- closed subset of $bcl^{\mu}(A)$ - A.

Hence $bcl^{\mu}(A) \cap U^{c} = \phi$ and $bcl^{\mu}(A) \subseteq U$.Therefore A is bT^{μ} - closed.

Theorem: 3.10 If A is bT^{μ} -closed set in a supra topological space (X,μ) and $A \subseteq B \subseteq bcl^{\mu}(A)$ then B is also bT^{μ}- closed set.

Proof: Let U be T^{μ}- open in set (X,μ) such that $B \subseteq U$. Since $A \subseteq B \Rightarrow A \subseteq U$ and since A is bT^{μ} -closed set in (X, μ) $bcl^{\mu}(A) \subseteq U$, since $B \subseteq bcl^{\mu}(A)$. Then $bcl^{\mu}(B) \subseteq U$. Therefore B is also bT^{μ} - closed set in (X,μ)

Theorem: 3.11 Let A be bT^{μ} - closed set then A is b^{μ}- closed iff $bcl^{\mu}(A)$-A is T^{μ}- closed.

Proof: Let A be bT^{μ}- closed set.If A is b^{μ}- closed, we have $bcl^{\mu}(A)\text{-}A = \phi$, which

is T^{μ}- closed. Conversely, let $bcl^{\mu}(A)$-A is bT^{μ} - closed. Then by the theorem 3.13, $bcl^{\mu}(A)$ - A does not contain any non empty T^{μ}- closed and $bcl^{\mu}(A)\text{-}A=\phi$. Hence A is b^{μ}- closed.

Theorem: 3.12 A subset $A \subseteq X$ is bT^{μ}- open iff $F \subseteq bint^{\mu}(A)$ whenever F is T^{μ}- closed and $F \subseteq A$.

Proof: Let A be bT^{μ} - open set and suppose $F \subseteq A$, where F is T^{μ}- closed. Then X-A is bT^{μ}- closed set contained in the T^{μ}- open set X-F. Hence $bcl^{\mu}(X\text{-}A) \subseteq X\text{-}F$. Thus $F \subseteq bint^{\mu}(A)$. Conversely, if F is T^{μ} - closed set with $F \subseteq bint^{\mu}(A)$ and $F \subseteq A$, then $X\text{-}bint^{\mu}(A) \subseteq X - F$. This implies that $bcl^{\mu}(X\text{-}A) \subseteq X\text{-}F$. Hence X-A is bT^{μ} - closed. Therefore A is bT^{μ} - open set.

Theorem: 3.13 If B is T^{μ}- open and bT^{μ} - closed set in X, then B is b^{μ}- closed.

Proof: Since B is T^{μ}- open and bT^{μ}- closed then $bcl^{\mu}(B) \subseteq B$, but $B \subseteq bcl^{\mu}(B)$. Therefore $B=bcl^{\mu}(B)$.Hence B is b^{μ}- closed.

Corollary:3.14 If B is supra open and bT^{μ} - closed set in X. Then B is b^{μ}-closed.

Theorem: 3.15 Let A be supra g^{μ} b-open and bT^{μ} - closed set. Then $A \cap F$ is T^{μ}- closed whenever F is supra b- closed.

Proof: Let A be supra g^{μ} b-open and bT^{μ}- closed set then $bcl^{\mu}(A) \subseteq A$ and also $A \subseteq bcl^{\mu}(A)$. Therefore $bcl^{\mu}(A) = A$. Hence A is supra b-closed. Since F is supra b-closed. Therefore $A \cap F$ is supra b-closed in X. Hence $A \cap F$ is T^{μ} - closed in X.

From the above theorem and example we have the following diagram

Supra closed
↓
Supra bT-closed → supra gb-closed
↓
Supra gbr-closed

4. bT^{μ}- CONTINUOUS FUNCTIONS.

Definition: 4.1 Let (X, τ) and (Y, σ) be two topological spaces and μ be an associated supra topology with τ . A function f: (X, τ) → (Y, σ) is called bT^{μ}- Continuous if $f^{-1}(V)$ is bT^{μ}- closed in (X,μ) for every closed set V of (Y, σ).

Definition: 4.2 Let (X, τ) and (Y, σ) be two topological spaces and μ be an associated supra topology with τ . A function f: (X, τ) → (Y, σ) is called bT^{μ}- irresolute if $f^{-1}(V)$ is bT^{μ}-closed in (X,μ) for every bT^{μ}-closed set V of (Y, σ).

Theorem: 4.3 Every continuous function is bT^{μ} - continuous.

Proof: Let f: $(X, \tau) \to (Y, \sigma)$ be a continuous function and A is closed in Y. Since f is continuous, then $f^{-1}(A)$ is a closed set in X. Since μ is associated with τ, then $\tau \subseteq \mu$. Therefore $f^{-1}(A)$ is supra closed in X and it is bT^{μ}-closed in(X,μ). Hence f is bT^{μ} - continuous.

Remark: 4.4 The converse of the above theorem need not be true as seen from the following example.

Example: 4.5 Let X =Y= {a, b, c}, τ = {X, ϕ {a}} and σ ={X,ϕ, {a}{b}{a, b}}.

Let f: $(X, \tau) \to (Y, \sigma)$ be a function defined by f(a) = c, f(b) = a, f(c)=b. Let f^{-1} ({b, c}) = {a, c} is bT^{μ}-closed but not closed. Then f is bT^{μ}-continuous but not continuous.

Theorem: 4.6 Every supra continuous function is bT^{μ} - continuous.

Proof: Let f: $(X, \tau) \to (Y, \sigma)$ be a supra continuous and A is supra closed in Y. Since f is supra continuous, then $f^{-1}(A)$ is supra closed in X. Since μ is associated with τ, then $\tau \subseteq \mu$. Therefore $f^{-1}(A)$ is supra closed and it is bT^{μ} - closed in (X, μ). Hence f is bT^{μ} - continuous.

Remark: 4.7 The converse of the above theorem need not be true as seen from the following example.

Example: 4.8 Let X ={a, b, c},τ = {X, ϕ, {a}} and σ = {Y, ϕ, {a} {b} {a, b}}. Let f :$(X, \tau) \to (Y, \sigma)$ be a function defined by f(a) = c, f(b) = a, f(c) = b. Let f^{-1}({b, c})={a, c} is is bT^{μ} -closed but not supra closed. Then f is bT^{μ}-continuous but not supra continuous.

Theorem: 4.9

(i) Every bT^{μ} - continuous is $g^{\mu}br$ - continuous.

(ii) Every bT^{μ}- irresolute is bT^{μ} - continuous.

Proof: (i) Let f :$(X, \tau) \to (Y, \sigma)$ be a bT^{μ} - continuous function. Let V be a supra closed set in Y. Since f is bT^{μ} -continuous, $f^{-1}(V)$ is bT^{μ} -closed in X. We know that every bT^{μ} -closed is $g^{\mu}br$ - closed set, then $f^{-1}(V)$ is $g^{\mu}br$ - closed set in X. Therefore f is $g^{\mu}br$ -continuous.

(ii) Suppose f : $(X, \tau) \to (Y, \sigma)$ be a bT^{μ}- irresolute .Let V be any supra closed set in Y, then V is bT^{μ}-closed. Since f is bT^{μ}-irresolute, f^{-1} is bT^{μ}-closed in X. Hence f is bT^{μ}-continuous.

Remark: 4.10 The converse of the above theorem need not be true as seen from the following examples.

Example: 4.11 (i) Let X=Y={a, b, c}, τ ={X, ϕ {a}{a, b}{b, c}} and σ = {Y, ϕ, {a}}.

Let f: $(X, \tau) \to (Y, \sigma)$ be a function defined by f(a) = c, f(b) = b, f(c) = a. f^{-1} {b, c} = {a, b} which is $g^{\mu}br$-continuous but not bT^{μ} - continuous

Example: 4.12 (ii) Let X=Y={a, b, c}, τ ={X, ϕ,{a}{a, b}{b, c}} and σ = {Y, ϕ, {a}{a, b}}.

Let f: $(X, \tau) \to (Y, \sigma)$ be a function defined by f(a) = c, f(b) = b, f(c) = a. Then f is bT^{μ}-continuous. Since f^{-1} {b, c} = {a, b} is not bT^{μ} closed in (X, τ).Therefore f is not bT^{μ}-irresolute.

Theorem: 4.13 Let f :$(X, \tau) \to (Y, \sigma)$ and g : $(Y, \sigma) \to (Z, \gamma)$ be any two function then

(i) gof is bT^{μ} -continuous if g is supra continous and f is bT^{μ} -continuous.

(ii) gof is bT^{μ}- irresolute if g is bT^{μ} - irresolute and f is bT^{μ} - irresolute.

(iii) gof is bT^{μ} -continuous if g is bT^{μ} -continuous and f is bT^{μ} - irresolute.

Proof: (i) Let V be supra closed in (Z, γ). Then $g^{-1}(V)$ is supra closed in (Y, σ). Since g is supra continuous, then $f^{-1}(g^{-1}(V))=(gof)^{-1}(V)$ is bT^{μ}-closed in (X, τ). Hence gof is bT^{μ}-continuous.

(ii) Let V be bT^{μ}-closed in (Z, γ).Then $g^{-1}(V)$ is bT^{μ}-closed in (Y, σ). Since g is bT^{μ}-irresolute, then $f^{-1}(g^{-1}(V))=(gof)^{-1}(V)$ is bT^{μ}-closed in (X, τ). Hence gof is bT^{μ}-irresolute.

(iii) Let V be supra closed in (Z, γ).Then $g^{-1}(V)$ is bT^{μ}-closed in (Y, σ). Since g is bT^{μ}-continuous, then $f^{-1}(g^{-1}(V))=(gof)^{-1}(V)$ is bT^{μ}-closed in (X, τ). Hence gof is bT^{μ}-continuous.

Remark: 4.14 The composition of two bT^{μ}-continuous function need not bT^{μ}- continuous and it is shown by the following example.

Example: 4.15 Let $X=\{a,b,c,d\}$, $\tau=\{X,\phi,\{a\}\{b\}\{a,b\}\}$ and $\sigma=\{X,\phi,\{a\}\{c\}\{a,c\}\}$

Let f: (X, τ) $\rightarrow$ (X, τ) be a function defined by f(a) = b, f(b) = c, f(c) = d and f(d)=a.

Let g: (X, τ) $\rightarrow$ (X, σ) be a function defined by g(a) = b, g(b) = c,g(c) =d and g(d)=a. Then f and g are bT^{μ}-continuous, since {b, c, d} is supra closed in (X, σ), $(gof)^{-1}$ {b, c, d} ={a, b, d} which is not bT^{μ}-closed in (X, τ). Therefore gof is not bT^{μ}- continuous.

From the above theorem and example we have the following diagram

Continous →Supra continuous
↓ ↓
Supra bT-continuous ← supra bT-irresolute
↓
Supra gbr- continuous

5. APPLICATIONS

Definition: 5.1 A supra topological space (X,μ) is called ${}_{bT}T_c^{\mu}$-space. If every bT^{μ}-closed set is supra closed set.

Theorem: 5.2 Let (X,τ) be a supra topological space then
(i) $O^{\mu}(\tau)\subset BT^{\mu}O(\tau)$
(ii) A space (X,τ) is ${}_{bT}T_c^{\mu}$-space iff $O^{\mu}(\tau) = BT^{\mu}O(\tau)$.

Proof:
(i) Let A be supra open. Then X-A is supra closed and so bT^{μ}-closed. This implies that A is bT^{μ}-open. Hence $O^{\mu}(\tau)\subset BT^{\mu}O(\tau)$.

(ii) Let (X,τ) be ${}_{bT}T_c^{\mu}$-space. Let A $\in BT^{\mu}O(\tau)$, then X-A is bT^{μ}-closed. By hypothesis X-A is supra closed and thus A $\in O^{\mu}(\tau)$. Hence $O^{\mu}(\tau) = BT^{\mu}O(\tau)$. Conversely, let $O^{\mu}(\tau) = BT^{\mu}O(\tau)$.Let A be bT^{μ}-closed, then X-A is bT^{μ}-open.

Hence X-A is supra open. Thus X is supra closed. This implies (X,τ) is ${}_{bT}T_c^{\mu}$-space.

Theorem: 5.3 If (X,τ) is ${}_{bT}T_c^{\mu}$-space then for each x$\in$X, {x} is either bT^{μ}-closed or supra open.

Proof: Suppose (X,τ) is ${}_{bT}T_c^{\mu}$-space. Let x$\in$X and assume that {x} is not supra open, then X-{x} is not supra closed. Then X-{x} is bT^{μ}-closed. Since (X,τ) is ${}_{bT}T_c^{\mu}$-space, then X-{x} is supra closed or equivalently {x} is supra open.

Definition: 5.4 A supra topological space (X,μ) is called ${}_{gb}T_{bT}^{\mu}$-space. If every $g^{\mu}b$-closed set is bT^{μ}- closed set.

Theorem: 5.5 Let (X,τ) be a supra topological space then
(i)$BT^{\mu}O(\tau)\subset G^{\mu}BO(\tau)$
(ii) A space (X,τ) is ${}_{gb}T_{bT}^{\mu}$-space iff $BT^{\mu}O(\tau) = G^{\mu}BO(\tau)$.

Proof: (i) Let A be bT^{μ}- open. Then X-A is bT^{μ}- closed and so $g^{\mu}b$-closed. This implies that A is $g^{\mu}b$-open. Hence $BT^{\mu}O(\tau)\subset G^{\mu}BO(\tau)$.

(ii) Let (X,τ) be ${}_{gb}T_{bT}{}^{\mu}$-space. Let $A \in G^{\mu}BO(\tau)$, then X-A is g^{μ}b-closed. By hypothesis X-A is bT^{μ}- closed and thus $A \in BT^{\mu}O(\tau)$. Hence $BT^{\mu}O(\tau) = G^{\mu}BO(\tau)$.Conversely, let $BT^{\mu}O(\tau) = G^{\mu}BO(\tau)$.Let A be g^{μ}b-closed, then X-A is g^{μ}b-open. Hence X-A is bT^{μ}- open. Thus X is bT^{μ}- closed. This implies (X,τ) is ${}_{gb}T_{bT}{}^{\mu}$-space.

Theorem: 5.6 If (X,τ) is ${}_{gb}T_{bT}{}^{\mu}$-space then for each $x \in X$, $\{x\}$ is either g^{μ}b-closed or bT^{μ}- open.

Proof: Suppose (X,τ) is ${}_{gb}T_{bT}{}^{\mu}$--space. Let $x \in X$ and assume that $\{x\}$ is not bT^{μ}- open, then X-{x} is not bT^{μ}-closed. Then X-{x} is g^{μ}b -closed. Since (X,τ) is ${}_{gb}T_{bT}{}^{\mu}$-space, then X-{x} is bT^{μ}-closed or equivalently {x} is bT^{μ}-open.

Definition: 5.7 A supra topological space (X, μ) is called ${}_{gbr}T_{bT}{}^{\mu}$- space.If every g^{μ}br-closed set is bT^{μ}- closed set.

Theorem: 5.8 Let (X,τ) be a supra topological space then
(i)$BT^{\mu}O(\tau) \subset G^{\mu}BRO(\tau)$
(ii) A space (X,τ) is ${}_{bT}T_{c}{}^{\mu}$-space iff $BT^{\mu}O(\tau) = G^{\mu}BRO(\tau)$.

Proof: (i) Let A be bT^{μ}- open. Then X-A is bT^{μ}- closed and so g^{μ}br-closed. This implies that A is g^{μ}br-open. Hence $BT^{\mu}O(\tau) \subset G^{\mu}BRO(\tau)$.

(ii) Let (X,τ) be ${}_{gbr}T_{bT}{}^{\mu}$-space. Let $A \in G^{\mu}BRO(\tau)$, then X-A is g^{μ}br-closed. By hypothesis X-A is bT^{μ}- closed and thus $A \in BT^{\mu}O(\tau)$. Hence $BT^{\mu}O(\tau) = G^{\mu}BRO(\tau)$.Conversely, let $BT^{\mu}O(\tau) = G^{\mu}BRO(\tau)$.Let A be g^{μ}br-closed, then X-A is g^{μ}br-open. Hence X-A is bT^{μ}- open. Thus X is bT^{μ}- closed. This implies (X,τ) is ${}_{gbr}T_{bT}{}^{\mu}$-space.

Theorem: 5.9 If (X,τ) is ${}_{gbr}T_{bT}{}^{\mu}$-space then for each $x \in X$, $\{x\}$ is either g^{μ}br-closed or bT^{μ}- open.

Proof: Suppose (X,τ) is ${}_{gbr}T_{bT}{}^{\mu}$--space. Let $x \in X$ and assume that $\{x\}$ is not bT^{μ}- open, then X-{x} is not bT^{μ}-closed. Then X-{x} is g^{μ}br -closed. Since (X,τ) is ${}_{gbr}T_{bT}{}^{\mu}$-space, then X-{x} is bT^{μ}-closed or equivalently {x} is bT^{μ}-open.

Theorem: 5.10
(a) Every ${}_{gbr}T_{bT}{}^{\mu}$-space is ${}_{bT}T_{c}{}^{\mu}$-space.
(b) Every ${}_{gbr}T_{bT}{}^{\mu}$-space is ${}_{gb}T_{bT}{}^{\mu}$-space.
(c) Every ${}_{bT}T_{c}{}^{\mu}$-space is ${}_{gb}T_{bT}{}^{\mu}$-space.

Proof: It is obvious.

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