Delving
Journal of Technology and Engineering Science
ISSN 0975-5289
June 2019
Vol. 2 Issue 2

Articles

ACROPOLIS
Enlightening wisdom

Acropolis Institute of Technology & Research Indore
www.acropolis.in

Journal of Technology and Engineering Science

ISSN 0975-5289

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A review paper

Utilisation of the Ayurvedic Drug Triphala in Various Maladies

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Abstract: Human beings live in the ayurvedic medicinal system is the oldest therapeutic system. In this Triphala, is widely used, to treat so many health-related issues. Triphala powder is made with the combination of three different fruits, *Terminalia chebula*, *Terminalia bellerica*, and *Phyllanthus emblica*. According to Ayurveda, this powder is used as a Laxative, Purgative, Asthma, Vomitings, Throat infections, Bleeding Piles, Heart diseases and Bladder related diseases. This Powder is having more Anti-oxidants, Anti-bacterial, anti-inflammatory, and Anti-cancer the tendency controls the production of insulin. This powder is more important because of all these good qualities.

***Key-words*:** Triphala, Anti-inflammatory, Anti-cancer, Ayurveda

I. Introduction

Before the appearance of present-day prescription, Ayurveda, the customary arrangement of Indian drug, which when translated signifies "study of life," was the foundation of the human services framework in old India. Ayurveda has its underlying foundations in the Vedas, which goes back to almost 5000 years BC, and early literary works like the *Charaka Samhita* and *Sushruta Samhita*, expounded on 1000 years BC, which give an itemized record on the indicative strategies and treatment expected to oversee different afflictions and illnesses of the two people and tamed creatures [1, 2].

Ayurveda is a necessary piece of the Indian culture and materia medica, and even today remains a compelling arrangement of medication. Assessments are that about 70% of India's populace depends on the utilisation of Ayurvedic medicines and their restrictive medicines for the treatment and prevention of different afflictions and illnesses. Ayurveda and its varieties are likewise polished far and wide, and in Europe and the United States, it is viewed as a correlative and elective medication [3].
The idea and treatment standards of Ayurveda are unique about those of current medication. While a present-day prescription is proof-based and utilizes a particular well-characterized synthetic element for treatment, accentuation in Ayurveda is chiefly on infection anticipation and advancement of good wellbeing by following a legitimate way of life and adopting measures that revive the cells of the body [1, 4].

As per Ayurvedic reasoning, the body is comprised of Tridoshas (three senses of humor), *Saptha Dhatus* (seven kinds of tissues), and *Malas* (squander items). Every one of the three is comprised of *Panchamaha boot has*, the five essential components of the universe: earth, water, fire, air, and ether [1, 7]. The three *Doshas* comprise the *Vata* (wind or breeze in Sanskrit), the *Pitta* (fire or bile), and the *Kapha* (water or bodily fluid).

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As per Ayurveda, *Vata* is identified with physical development and the sensory system and is in charge of cell separation [7]. *Pitta* alludes to the gastric juices and other cell proteins in cost of the assimilation and biotransformation of sustenance, drugs, and xenobiotics [7]. It is likewise thought to be engaged with the age and protection of body heat [5]. *Kapha* identifies with dampness in the tissues and real organs of the body [7]. *Kapha and Pitta* are progressively anabolic, while *Vata* is catabolic [7]. The idea of Tridoshas is like that of the Greek way of thinking and might be compared to air *(Vata*), bile *(Pitta*), and mucus (*Kapha*), individually [5]. *Tripathi* [6] recommends that these Tridoshas at the atomic level are in charge of different capacities: *Vata* for film bound sign transduction, *Pitta* for flagging moieties and compounds, and *Kapha* for quality and protein articulation. For the ideal working of the body, the *Tridoshas* should be in a condition of balance with one another, and any adjustments influence the typical capacities and strength of the person. The parity in *Tridosha* is very touchy and is defenseless to variety because of ecological changes (diurnal, nocturnal, and occasional adjustments), modified way of life (changes in nourishment propensities, physical movement), and age [5]. The other significant part of Ayurvedic reasoning is the concept of the *Saptha Dhatus* or seven tissue frameworks. These are *Rasa* (plasma or lymph), *Raktha* (platelets), *Mamsa* (muscle), *Medas* (fat), *Asthi* (bones), *Majja* (marrow), and *Sukra* (semen) [7,]. As per Ayurveda, *Rasa Dhatu* is the most significant as it sustains the various tissues, and *Ojas* is the final product of the resulting anabolic procedure [5,7]. *Ojas* is a magnificent body component, and its amount and quality are in charge of the ideal working of the body. It is likewise accepted that *ojas* improves the performance of the body and expands opposition against infections and illnesses, accordingly bringing about a stable life [7].

II. **Regular Forms of Triphala**

In Ayurvedic work on, contingent upon the *Dosha*, Triphala is utilized for different infirmities – for instance, to avoid obstruction, as a colonic and gastrointestinal tract tonifier, an intestinal chemical and a stomach related; for nourishment osmosis support; to keep up serum cholesterol level, improve the course, and loosen up the bile pipe; for drowsy peristalsis; as a cell reinforcement; for cerebral pains; to secure the kidney; and furthermore as a hepatoprotective specialist [2, 8]. Different arrangements of Triphala are accessible – as *churna* (fine powder), *kwacha* (decoction), *Mashi* (fiery debris), *taila* (oil), or *grit* (Triphala cooked with explained spread or ghee) – relying upon the state of the patient and the sickness [9] 10].

Triphala churna and *kwacha* are the most uncomplicated and most ordinarily utilized structures, made by powdering the three constituents. On account of churna, the dry organic product pulps of all the three myrobalans are blended in the proportion of either 1:1:1 or 1:2:4 of Haritaki, Bibhitaki, and Amalaki, respectively, and is finely powdered.

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Botanical description

Figure 1. Triphala is a mixture of three ayurvedic fruits: A) Haritaki B) Amalaki C) Bibhitaki

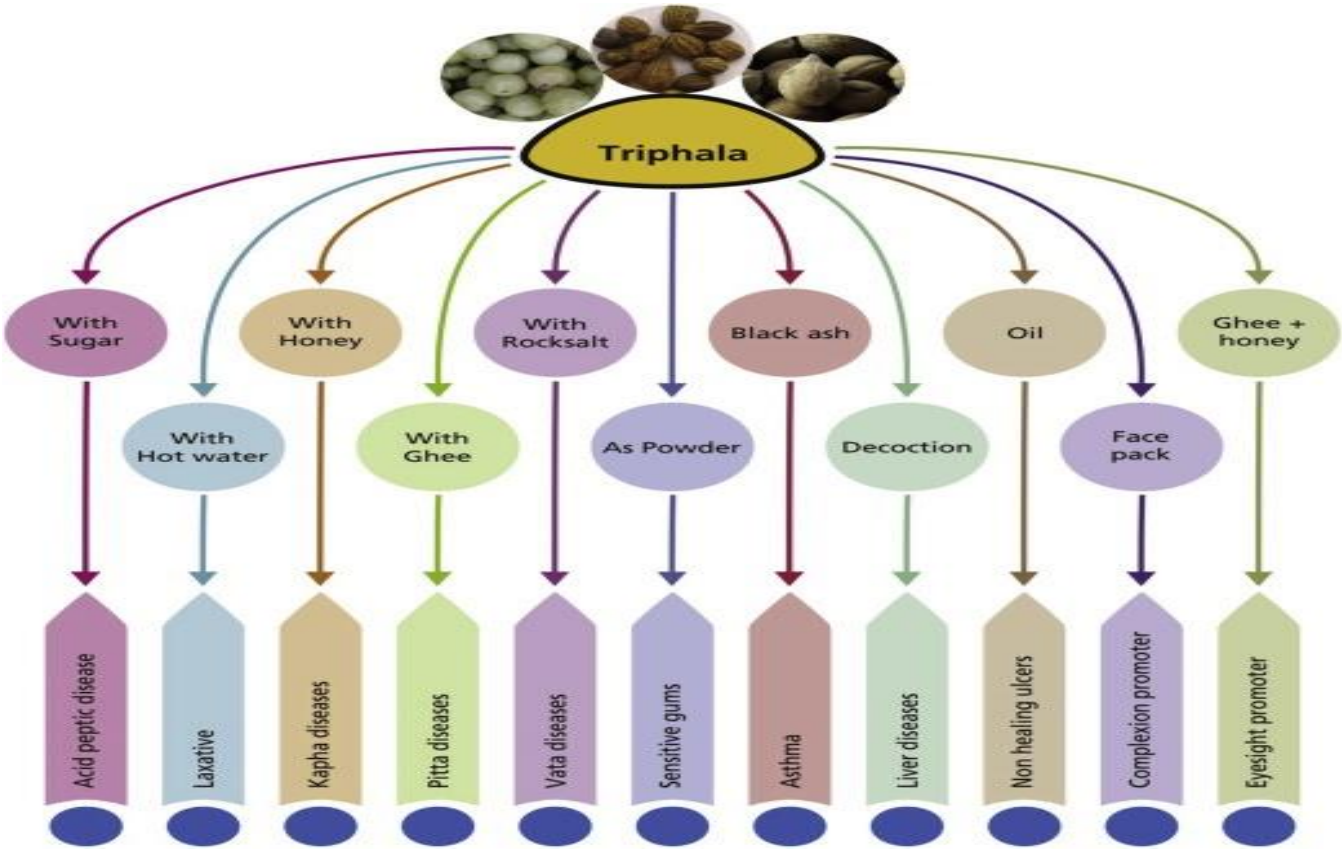

Figure 2. Multidimensional effects of Triphala.

Terminalia chebula- this tree is tall of having max. The height of 80 feet. Branches are spread like a round crown, having dark brown coloured bark with longitudinal streaks on it. Leaves are ovate with two large oil glands at the tip of the petiole. Flowers are having small panicle, white, creamish white to yellow with a strong unpleasant smell. The flowers are monoecious, starts flowering in the month of May-June and fruiting from July to December. Fruit ripening occurs between

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November to March and falls soon after ripening. The fruit is ovate, drupe, 2-4 cm long, having green colour before during. After drying, it becomes hard, having 5-6 longitudinal streaks, yellowish-grey and hard for touching — fruit formation from Nov-Jan [11] only.

Terminalia bellirica- it's a big deciduous tree having 30 meters in length with leaves 15cm long, crowded at the tip of the branches. Flowers are simple, solitary, unisexual flowers, white or yellow, with an offensive odour. Male roses are available in the upper part of the tree and female flowers in the lower part. Flowering starts in May. The fruit is grey coloured drupe, ovoid, sweet kernels inside. It resembles myrobalan fruit, but without ridges. The seed is having oil glands in it, which is used in different treatments in Ayurveda.

Phyllanthus emblica: This is a medium-sized tree, having smooth bark, grows in deciduous forests. The leaves are feathery with small oblong pinnately arranged leaflets. Flowering occurs during the hot season, the fruiting in the winter. The fruit is fleshy, globose, compressed drupe, having 1.5 – 2.5 cm in diameter, in green when raw, after-ripening changes to light yellow or brick red colour. A small depression is present at one end, which is left due to the removal of the peduncle. The pericarp is shiny, having six furrows.

Ethnobotanical uses of Triphala powder: The Triphala powder is laxative, antispasmodic and stomachic. It is used as a cure for bleeding gums, ophthalmic, anti-inflammatory, wound healing. Increases appetite, liver activity, to control gastrointestinal propionate agent, chronic diarrhoea, used for nervous weakness, sore throat, control cough, other disorders of erythematous [12] it can cure constipation, diabetes, ulcers, colic pain, etc. This efficiently used to cure tumors [13]. Some diseases can be rectified immediately, like skin diseases, removal of constipation, for ulcer treatment, colic pain, haemorrhoids. It can control the blockages in the arteries (heart diseases).

III. Pharmacological activity

Cytoprotective activity

The Triphala powder has a high capacity to control cytotoxicity, with the GA (Gallic acid) and CA. By the equal proportion [14] of GA and CA, Anti-CD3 stimulation can be controlled very easily. The ethanolic acid in the Triphala powder will give a cytoprotective effect on the HEK-N/F cells and protects against UV induced oxidative damages to the cells. With these observations, we can see that it controls the age-dependent gene by shortening the length of the telomere. This can be observed in Southern blots by using restriction exonucleases. The DNA can be extracted from sub-culture passages [15]. This powder shows its cytoprotective effect on the gastric mucosa [16] and inhibitory action on cellular ageing.

Antidiabetic activity

This powder reduces the insulin levels in the blood. After the inducing streptozotocin in the diabetic rats for short and long time shows Reno protective activity [17, 18, 19].

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Antibacterial activity

Triphala powder is strong against intestinal Gram +ve, and Gram-ve bacteria [20, 21] Ethanedioic acid and ellagic acid, which are isolated from butanol is a strong antibacterial against E. coli and Clostridium perfingens [22]. This is effectively inhibiting Urease activity of Helicobacter pyroli, a ubiquitous bacterium which develops gastritis, ulcers and stomach cancers in the human intestine [23]. This powder effectively controls the Streptococcus aureus [24, 25] and inhibits the growth of Streptococcus mutants, a salivary bacterium [26]. This effectively controls the growth of *Xanthomonas competes for* PV. Citric, which causes citrus cancer disease [27]. This can control the growth of Salmonella typhi [28], Shigella and Klebsiella [29]. So Triphala powder acts as antibacterial [30,31].

Antifungal activity

The aqueous solution of Triphala powder acts against almost all the dermatophytes and yeasts [32, 33, 34] such as Candida albicans, dermatophytes Epidermophyton, Microsporum and Trichophyton rubrum [32]. It shows inhibition for three types of Trichophyton sp.(dermatophytes) and three species of *Candida spp*. (yeasts) Was documented [35]. The methanol extract from Triphala acts against clotrimazole resistant *Candida albicans*.

Antiviral activity

The Triphala powder can resist four immunodeficiency viruses' type-I(HIV-I) integrase inhibitors, three galloyl glucose (II-IV) and GA(I). Galloyl glucose inhibits the processing of HIV-I integrase compounds [36]. This powder acts against Influenza A virus which affects the epithelial cells. It protects against acute respiratory infections [37]. This Triphala powder can inhibit in vitro the replication of Human Cytomegalovirus (CMV) and acts as an immunosuppressive agent (mice) on AIDS model [Yukawa TA.,1992]. Triphala powder acts on Potato Virus [38].

Anti-inflammatory and anti-arthritic activity

By the synthesis of nitric oxide [39], Triphala powder acts as, anti-inflammatory agent. It can effectively suppress arthritis in mice [40,41]. Unending irritation is pernicious and influences most major interminable wellbeing conditions. Triphala has demonstrated guarantee as a calming operator. In one investigation, Triphala performed better or proportional when contrasted and standard medication treatment for an assortment of biochemical estimations of inflammation. [42] also, Triphala altogether decreased provocative markers just as bone and ligament debasement in joint rats. [43,44] In this examination, Triphala concentrate was essentially more successful than the nonsteroidal calming drug, indomethacin, in improving ligament and fiery impacts. Triphala decreased articulation of incendiary referees, for example, IL-17, COX-2, and RANKL through restraint of NF-κB enactment. Another examination found that Triphala expanded cancer prevention agent levels and diminished lipid peroxidation in the tissues of joint rats.[45] In lipopolysaccharide-animated macrophages, Triphala treatment stifled generation of provocative go-betweens, (for example, TNFα, IL-1β, IL-6, MCP-1, VEGF, NO, and PGE2), intracellular free radicals, fiery compounds, (for example, iNOS and COX-2), and lysosomal chemical release. Chebulagic corrosive, a constituent in Triphala, was found to repress COX and 5-LOX, which are

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both vital proteins engaged with irritation and carcinogenesis [13]. Triphala additionally expanded cell reinforcement action in mice after enlistment of nephrotoxicity from bromobenzene. Triphala enhanced nephrotoxic impacts by upregulating cell reinforcement catalysts, superoxide dismutase, glutathione-S-transferase, and glutathione peroxidase. Lipid peroxidation and markers of kidney brokenness were diminished in the Triphala-treated gathering contrasted and controls. [46] The mitigating impacts of Triphala ought to be explored in more exceptional detail.

Gastrointestinal motility and anti-ulcerogenic activity

The Triphala powder is used as a laxative and can increase gas removal time [47]. This improves the secretion capacity of Brunner's gland, which involves the protection of duodenal ulcers [48] and increases the protective power to the gastrointestinal mucosa.

Wound healing activity

The alcohols those are present in Triphala powder, having a high capacity to heal the wounds very fast by decreasing the time of epithelialisation [49].

Purgative property

The oils that are present in the Triphala powder is having high purgative power [50].

Anti-oxidant activity

Triphala powder has a high capacity to act as an antioxidant by the presence of the phenolic activity. This can easily remove the DPPH radicals [51] and controls the oxidase activity of Xanthine. The polyherbal formula Aller-7 controls the haemolysis and efficiently controls the release of nitric oxide from lipopolysaccharides, which are stimulating murine macrophages [52]. The aqueous solution of Triphala powder, the extract of methanolic have a high capacity to control the formation of radiation-induced lipid peroxide in rats. They remove the hydroxyl and superoxide activity from the cells [53]. Than alpha-tocopherol, the extracts of Acetone shows vigorous antioxidant activity. By the HPLC analysis, along with diode array method, detects the presence of different derivatives like hydroxyl cinnamic acid, hydroxybenzoic acid, flavanol aglycones, their glycosides as the main phenolic compounds [54].

Anti-carcinogenic activity

Some phenolics in Triphala powder [55] can inhibit the growth of cancer cells. They are chebulinic acid, tannic acid and ellagic acid were the most growth inhibitory phenolics in humans and rats. The ethanol that was extracted from Triphala powder is having the capacity of multiplication of cell can be inhibited and increases the cell death (in specific dosage) in malignant cell lines in humans (MCF-7) and Rat (S115) breast cancer cells, Human Osteosarcoma cell lines, Prostate cancer cells (PC-3) and some in-tumorogenic immortalized human prostate cell line (PNT1A) [13].

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Antimutagenic activity

The tannins present in the aqueous solution of Triphala powder has antimutagenic activity in Salmonella typhimurium [Grover IS., 1992]. These can prevent the breakage caused by Gamma radiations in the pBR322 plasmid DNA. If we treat the rat liver with this aqueous solution, then it can reduce the peroxidation of membrane lipids and controls the damage to the DNA strands by radiations. In vitro, this can control the damage caused by gamma radiations to human lymphocytes [56]. In male Wistar mice [57], Nickle chloride initiates renal oxidative stress, toxicity, and cell proliferation can be controlled by the aqueous solution of Triphala powder.

Hepatoprotective activity

Ethanol that is present in Triphala powder can effectively control hepatotoxicity caused by rifampicin, isoniazid & pyrazinamide [58].

Cardioprotective activity

By the pre-treatment with the Triphala powder, we can control the myocardial damage in rats [59]. This effects on isoproterenol on liquid peroxide and identifies the marker enzymes to stop this myocardial damage.

Antiprotozoal activity

The Triphala powder shows ant plasmodial action against Plasmodium falciparum [60].

Adaptogenic activity

Triphala powder was among the other three ayurvedic plants which can control different stressors in animals working in different ways [61]. This controls histamine levels showing anti anaphylactic action [54]. The Triphala powder can increase the effect on anti-dinitrophenyl Ig E, which induces a tumour in rats can be controlled by the production of alpha from rat peritoneal mast cells. This indicates the anti-anaphylactic action [62].

Hypocholesterolaemia activity

Triphala powder can control the hypolipidemic movement [63] and also monitors hypocholesterolaemia activity against cholesterol. If cholesterol increase, it leads to hypercholesterolemia and atherosclerosis in rabbits [64]. Triphala powder can easily manage these problems.

Antispasmodic activity

The Triphala powder can easily control the Ani-spasmodic or Anti-vata problem by reducing blood pressure and intestinal spasms. By this, we can easily say that Triphala has Traditional Ayurvedic uses, for controlling spastic colon and other intestinal disorders [65].

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Immunomodulatory activity

The aqueous solution of Triphala controls the hypersensitivity in mice and increases humoral antibodies [66]. The Triphala powder controls the cellular immune response in an amoebic liver abscess in Golden hamsters [67].

Clinical studies

By oral rinsing of the Triphala powder, it can easily control the bacterial as well as streptococcus bacterial count in Saliva. After rinsing, this may last for 3hrs, having the capacity for preventing dental caries [68]. Triphala powder shows sound effects on constipation, mental and physical disability, allergic rhinitis and mental stress. The drugs present in this powder will work on the specific organ to control the effect, not causing any side effects nor acts on any other part of the body adversely [69].

Safety evaluation

From the literature of Triphala powder, it was noted that this could show its significant effects on cardioprotective [70], hepatoprotective [53], antimutagenic or anticarcinogenic, cytoprotective [71], antioxidant [72,] and adaptogenic [73]. The extracts ethanol, aqueous and ethyl acetate also shown no toxic effects on sheep erythrocytes, on rat by using specific doses [74]. Triphala can reduce lead and aluminium-induced genotoxicity [75]. The tannins obtained from Triphala powder has shown antimutagenic activity against mutagens like sodium azide and 4-nitro-O-phenylenediamine. With this, we can say that this powder is safe to use as a drug.

IV. Conclusions and Recommendations

Terminalia chebula, *Terminalia bellerica,* and *Phyllanthus emblica* are versatile plants and having extensive pharmacological and medicinal activities. The powder that was made by these three plants, having several chemical substances, shows more pharmacological activities. This Triphala powder was the conventional medicine from the ancient period, used in Ayurveda to treat so many health problems, at that time itself. Now, we need to investigate more on this, to show the drug-resistant infections. Based on the need of the medicines which does not have any side effects, now we have to take the medication with these compounds, for different types of diseases and many health problems.

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Conflict of Interest Statement:

Manuscript title: Utilisation of the Ayurvedic Drug Triphala in various maladies

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Approximate Solution of System of Linear Equations by Pseudo Inverse and SVD Using MATLAB

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Abstract: In this paper, I will talk how the solution of system of linear equations can be approximated by calculating pseudo inverse and singular value decomposition (SVD) using MATLAB, when the exact solution of the system is not known to us. Here, we will solve the non – homogeneous system of linear equations in two or more than two variables.

Key-Words: pseudo inverse, svd, matlab, non – homogeneous, approximate, system.

I. Introduction

Consider a non – homogeneous linear system $AX = b$, where matrix A is a square matrix of order n. Moreover, assume that A is a full rank matrix $(rank(A) = n)$ i.e. A is non – singular matrix, then the linear system has a unique exact solution given by

$$X = A^{-1}b$$

If A is a rectangular matrix of order $m \times n$, then we cannot find the inverse of matrix A. so, how can we solve the linear system of equations $AX = b$. In this case, we can find the approximate solution of it by using Pseudo Inverse and Singular Value Decomposition (SVD). We will discuss two type of systems of non – homogeneous linear equations namely Over determined and Underdetermined systems. Also, we will use the MATLAB software for matrix computations.

II. Approximate Solution by Pseudo Inverse

Over determined System

Consider a non – homogeneous linear system $AX = b$, where A is $m \times n$ matrix such that $m > n$ i.e. the number of equations are more than unknown variables. This type of system is known as Overdetermined system. Moreover, assume that the system does not have an exact solution. Hence, we need to find the approximate solution which minimize the residual error, $E = \| AX - b \|^2$

i.e. $$E = (AX - b)^T (AX - b)$$

For finding the extrema of E, we partially differentiate w.r.t. X and using $\frac{\partial E}{\partial X} = 0$

$$E = (AX - b)^T (AX - b) = (X^T A^T - b^T)(AX - b)$$
$$= X^T A^T AX - X^T A^T b - b^T AX + b^T b$$

$$= X^T A^T AX - 2X^T A^T b + b^T b$$

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Now, using $\frac{\partial E}{\partial X} = 0$, we have

$$\Rightarrow \quad 2A^TAX - 2A^Tb = O \quad \Rightarrow \quad X = (A^TA)^{-1}A^Tb$$

where A^TA is an invertible matrix of order $n \times n$.

If we write $(A^TA)^{-1}A^T = A^+$, then the least square solution of the system $AX = b$ is $X = A^+b$.

Here, the matrix $A^+ = (A^TA)^{-1}A^T$ is called the **Pseudo inverse** of the matrix A.

Illustration with MATLAB

Find the least square solution of the system of linear equations

$4x + 3y + 3z + t = 9$

$x + 2y + z + t = 2$

$3x + 4y + 2z - t = 8$

$2x + 3y + 4z + 5t = 5$

$x - y + z - t = 4$

In matrix form, the overdetermined system can be written as

$$\begin{bmatrix} 4 & 3 & 3 & 1 \\ 1 & 2 & 1 & 1 \\ 3 & 4 & 2 & -1 \\ 2 & 3 & 4 & 5 \\ 1 & -1 & 1 & -1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ t \end{bmatrix} = \begin{bmatrix} 9 \\ 2 \\ 8 \\ 5 \\ 4 \end{bmatrix}$$

$$\Rightarrow \quad AX = b$$

where $A = \begin{bmatrix} 4 & 3 & 3 & 1 \\ 1 & 2 & 1 & 1 \\ 3 & 4 & 2 & -1 \\ 2 & 3 & 4 & 5 \\ 1 & -1 & 1 & -1 \end{bmatrix}$, $X = \begin{bmatrix} x \\ y \\ z \\ t \end{bmatrix}$ and $b = \begin{bmatrix} 9 \\ 2 \\ 8 \\ 5 \\ 4 \end{bmatrix}$

Using MATLAB, we get $X = \begin{bmatrix} 1.0000 \\ 0.0000 \\ 2.0000 \\ -1.0000 \end{bmatrix}$

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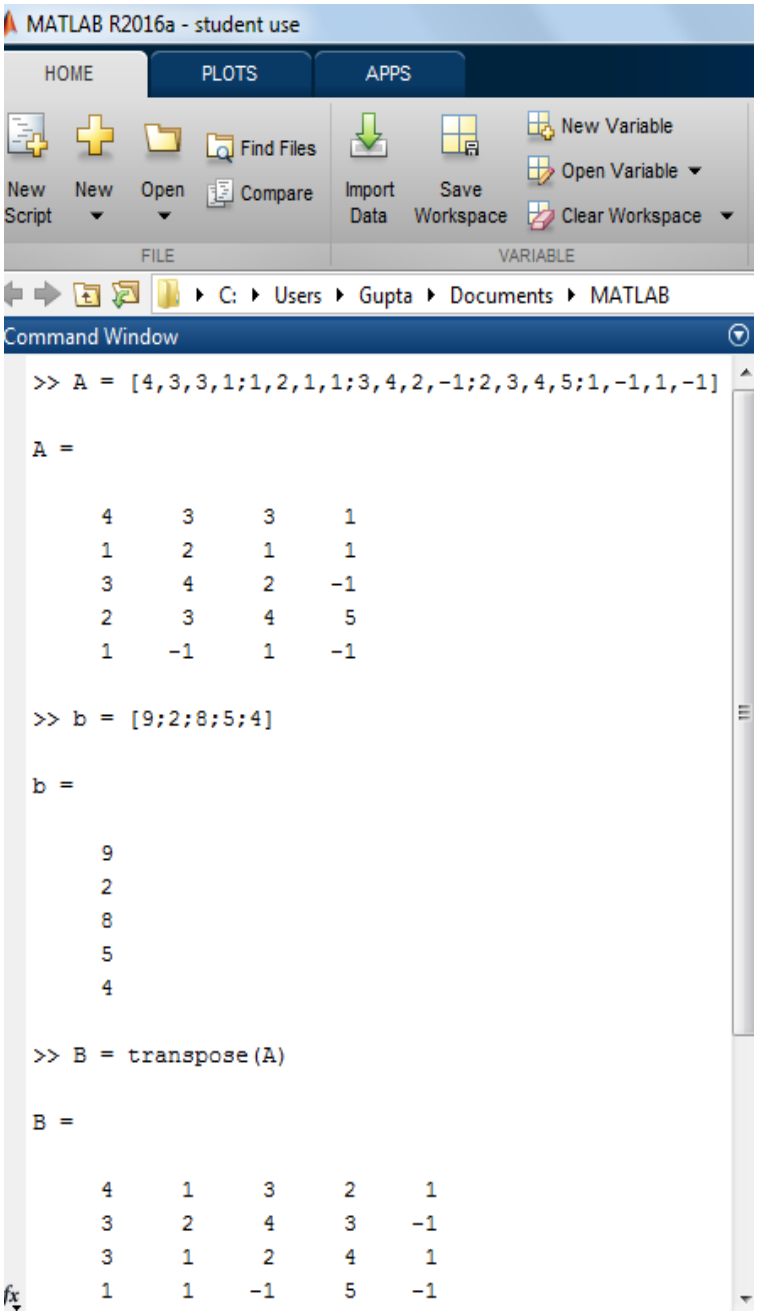

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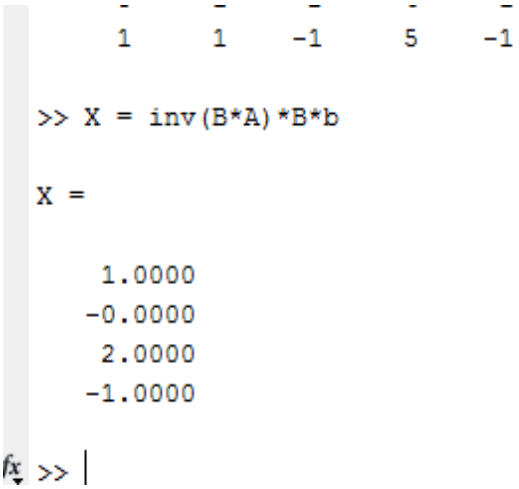

Figure 1: Approximate Solution of Overdetermined system with MAT LAB using Pseudo inverse.

Underdetermined System

Consider a non – homogeneous linear system $AX = b$, where A is $m \times n$ matrix such that $m < n$ i.e. the number of equations is less than unknown variables. It is underdetermined system having infinitely many solutions. Now, we need to pick one of these solutions by finding smaller one, i.e. $\min \| x \|^2$ subject to $AX = b$, by using method of Lagrange's Multiplier, we have

$$E = \| X \|^2 + \lambda^T (b - AX)$$

$$\frac{\partial E}{\partial X} = 0 \quad \Rightarrow \quad 2X - A^T\lambda = O \tag{1.1}$$

On pre – multiplying both sides by A, we get

$$2AX - AA^T\lambda = O \quad \Rightarrow \quad 2b - A\,A^T\lambda = O \quad \Rightarrow \quad \lambda = 2b(AA^T)^{-1}$$

Using in equation (1.1), we get

$$2X - 2A^T(AA^T)^{-1}b = O \quad \Rightarrow \quad X = A^T(AA^T)^{-1}b$$

where AA^T is an invertible matrix of order $m \times m$.

If we write $A^T(AA^T)^{-1} = A^+$, then the least square solution of the system $AX = b$ is

$X = A^+ b$.

Here, the matrix $A^+ = A^T(AA^T)^{-1}$ is called the **Pseudo inverse** of the matrix A.

Illustration with MATLAB

Find the least square solution of the system of linear equations

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$$x_1 + 2x_2 - 3x_3 - 2x_4 + 4x_5 = 1$$
$$2x_1 + 5x_2 - 8x_3 - x_4 + 6x_5 = 4$$
$$x_1 + 4x_2 - 7x_3 + 5x_4 + 2x_5 = 8$$

In matrix form, the underdetermined system can be written as

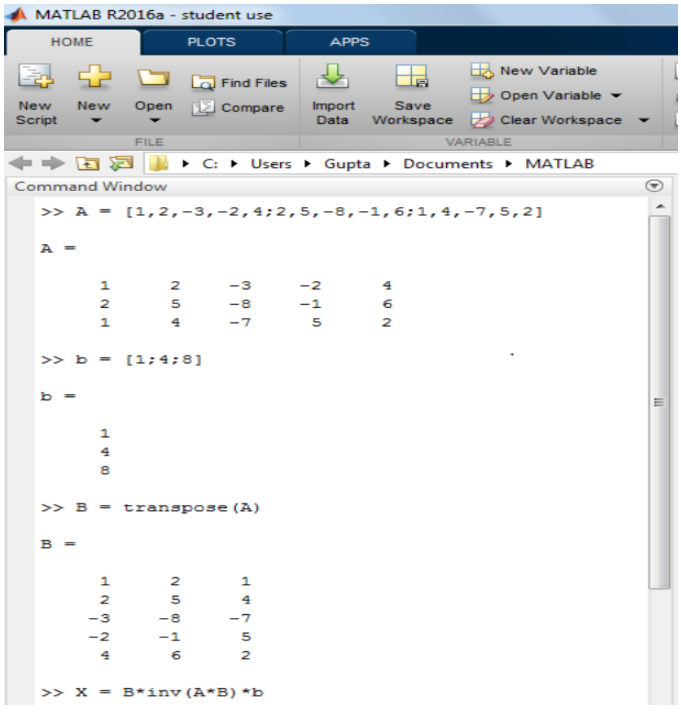
$$\begin{bmatrix} 1 & 2 & -3 & -2 & 4 \\ 2 & 5 & -8 & -1 & 6 \\ 1 & 4 & -7 & 5 & 2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix} = \begin{bmatrix} 1 \\ 4 \\ 8 \end{bmatrix}$$

$$\Rightarrow \quad AX = b$$

where $A = \begin{bmatrix} 1 & 2 & -3 & -2 & 4 \\ 2 & 5 & -8 & -1 & 6 \\ 1 & 4 & -7 & 5 & 2 \end{bmatrix}, X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix}$ and $b = \begin{bmatrix} 1 \\ 4 \\ 8 \end{bmatrix}$

Using MATLAB, we get

$$X = \begin{bmatrix} -0.0744 \\ -0.0229 \\ -0.0286 \\ 1.2414 \\ 0.8793 \end{bmatrix}$$



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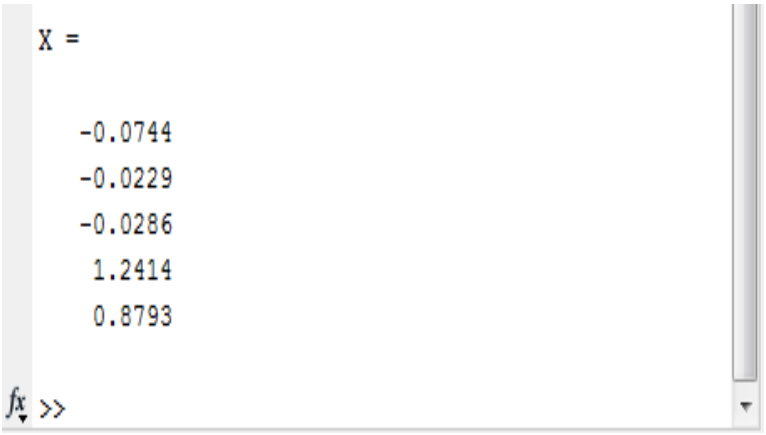

Figure 2: Approximate Solution of Underdetermined system with MATLAB using Pseudo Inverse

III. Approximate Solution by Singular Value Decomposition (SVD)

If the matrix A^TA is singular (i.e. $rank(A^TA) < n$), then $(A^TA)^{-1}$ does not exist. Now, the question arises that how to find the least square approximation of system $AX = b$. For doing this, we will use Singular Value Decomposition (SVD) of matrix A.

Singular Value Decomposition (SVD)

The singular value decomposition of a matrix A of order $m \times n$ is the factorization of matrix A into the product of three matrices i.e.

$$A = USV^T \tag{1.2}$$

Where U is a $m \times m$ orthogonal matrix, V is $n \times n$ orthogonal matrix and S is a $m \times n$ matrix containing singular values of A.

The singular values of A, denoted by $\sigma_1, \sigma_2, \dots, \sigma_r$, are the square root of the eigen values of AA^T or A^TA.

Consider a non – homogeneous linear system $AX = b$, where A is $m \times n$ matrix.

Using (2.1) , we get $(USV^T)X = b$

$\Rightarrow$ $X = (USV^T)^{-1}b$

$\Rightarrow$ $X = ((V^T)^{-1}S^+U^{-1})b$

$\Rightarrow$ $X = (VS^+U^T)b$

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Where the matrix S^+ is known as Pseudo inverse of matrix S and is defined as

$$\sigma_{ij}^{+} = \begin{cases} 0 & if\ \sigma_{ij} = 0 \\ \dfrac{1}{\sigma_{ij}} & if\ \sigma_{ij} \neq 0 \end{cases}$$

If A is $m \times n$ matrix and $rank(A) = r < \min\{m, n\}$, then

Either $rank(A) = r < n$ or $rank(A) = r < m$

If $rank(A) = r < n$, then the system is Overdetermined and if $rank(A) = r < m$, the the system is Underdetermined. In both the cases, $A^T A$ and AA^T are singular matrices of order $n \times n$ and $m \times m$ respectively, therefore the inverse of these matrices does not exist.

Then
$$S = \begin{bmatrix} \sigma_1 & 0 & 0 & 0 & 0 \\ 0 & \sigma_2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \sigma_r & 0 \\ 0 & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Here, the matrix S has $(m - r)$ zero rows and the singular values $\sigma_1, \sigma_2, \ldots, \sigma_r$ of A are non – negative real numbers satisfying $\sigma_1 \geq \sigma_2 \geq \cdots \geq \sigma_r \geq 0$.

The Pseudo inverse of S is given by

$$S^+ = \begin{bmatrix} \sigma_1 & 0 & 0 & 0 & 0 & \ldots & 0 \\ 0 & \sigma_2 & 0 & 0 & 0 & \ldots & 0 \\ 0 & 0 & 0 & 0 & 0 & \ldots & 0 \\ 0 & 0 & 0 & \sigma_r & 0 & \ldots & 0 \\ 0 & 0 & 0 & 0 & 0 & \ldots & 0 \end{bmatrix}$$

Here, the matrix S^+ has $(m - r)$ zero columns.

Therefore, $SS^+ = \begin{bmatrix} I_r & O \\ O & O \end{bmatrix}$ is an $m \times m$ matrix with '1' in the first r entries on the main diagonal, 0 elsewhere.

So, the least square solution of the system $AX = b$ is given by

$$X = (VS^+U^T)b = A^+b$$

where the matrix $A^+ = VS^+U^T$ is called **Pseudo inverse** of matrix A.

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Illustration with MATLAB

Find the least square solution of the system of linear equations

$4x + 3y + 3z + t = 9$

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$$\Rightarrow \quad AX = b$$

Where $A = \begin{bmatrix} 4 & 3 & 3 & 1 \\ 1 & 2 & 1 & 1 \\ 3 & 4 & 2 & -1 \\ 2 & 3 & 4 & 5 \\ 1 & -1 & 1 & -1 \end{bmatrix}, X = \begin{bmatrix} x \\ y \\ z \\ t \end{bmatrix}$ and $b = \begin{bmatrix} 9 \\ 2 \\ 8 \\ 5 \\ 4 \end{bmatrix}$

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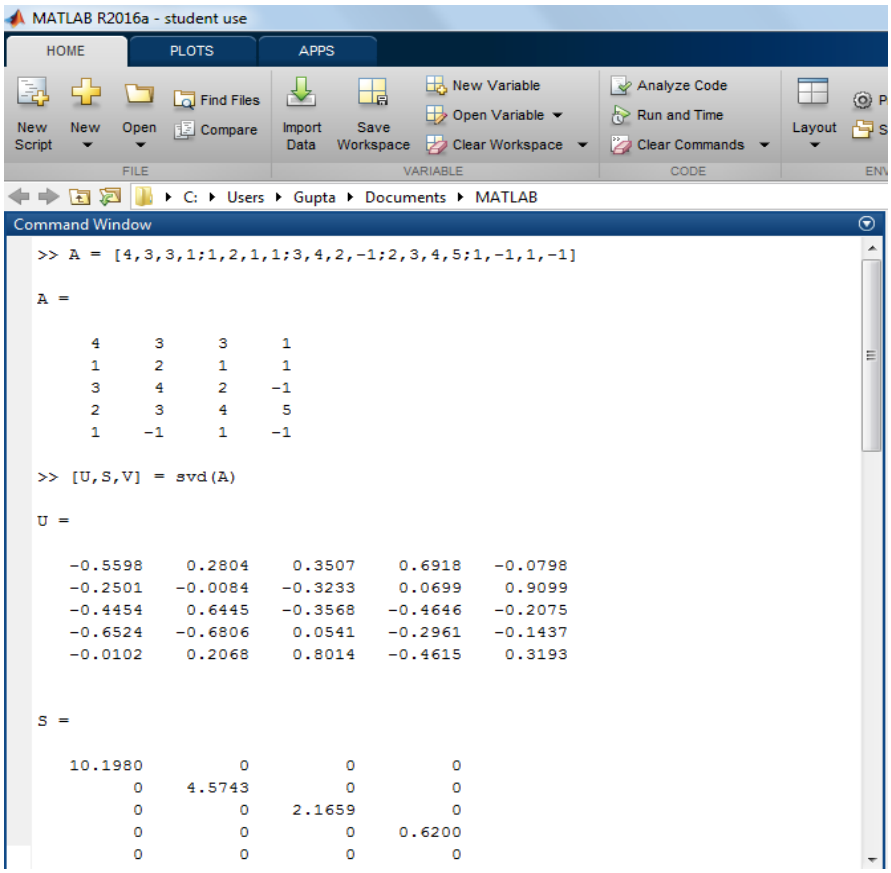

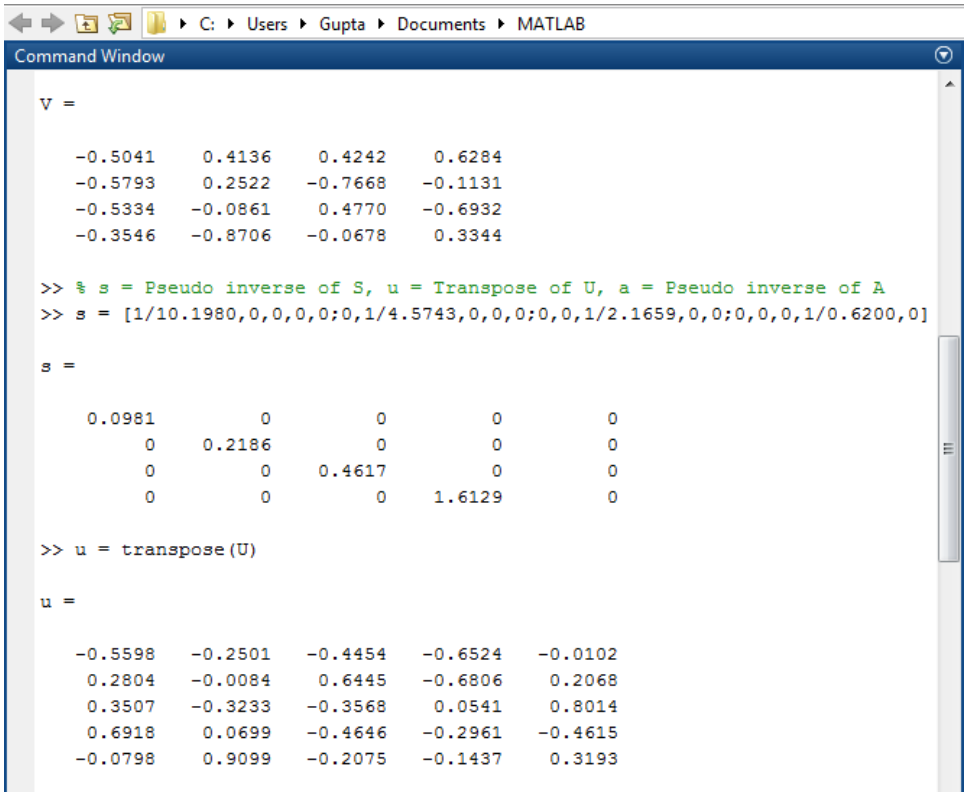

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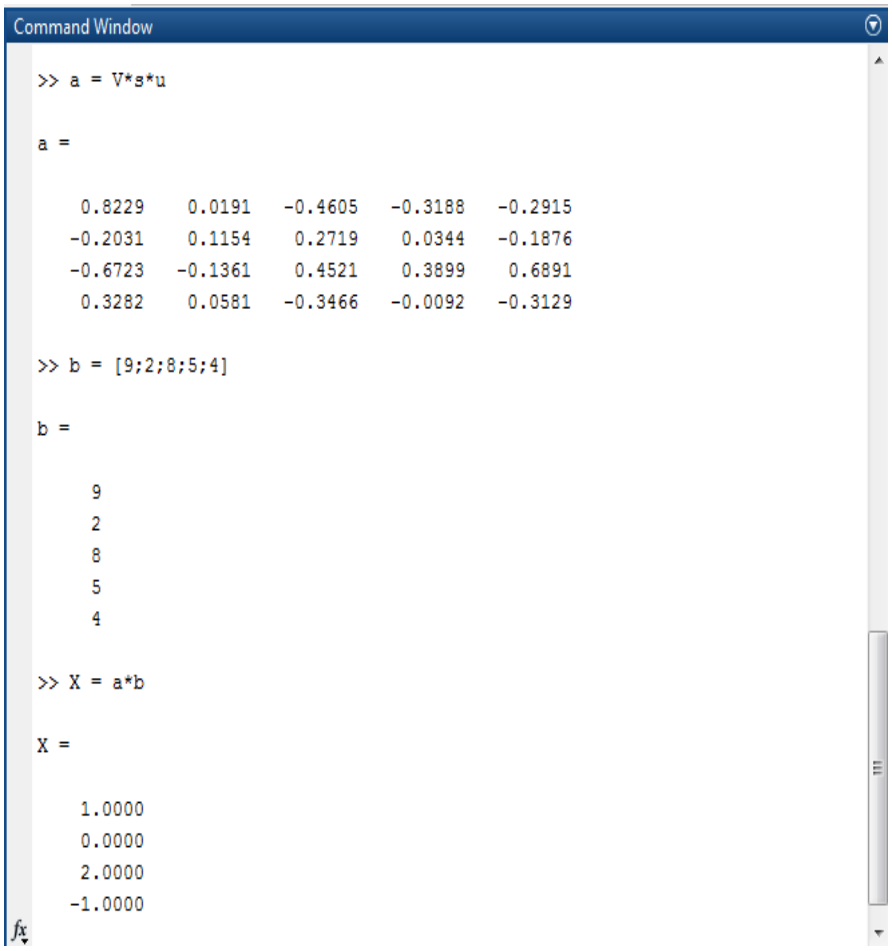

Figure 3: Approximate Solution of Overdetermined system with MATLAB using SVD

Note that the above approximate solution is same as calculated in Illustration 2.1.1 using Pseudo inverse of matrix A.

IV. Conclusion

In this paper, we study how to find Pseudo inverse of a rectangular matrix, singular value decomposition and approximate solution of non – homogeneous Underdetermined system and overdetermined systems using MATLAB. With the MATLAB, we can easily calculate the product, inverse, transpose etc. of matrices having any order. It is not an easy job to compute manually the product, inverse and transpose of matrices of higher order. So, MATLAB is the only software which can make these matrices computations very simple.

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Research Interest: Programming in MatLab, Programming in R Software, Computational Numerical Methods with MatLab

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Extended x-Ray k-Absorption Fine Structure (EXAFS) Studies of Copper II with Pyridine-2-Carboxamide and Amino Complexes

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Abstract: Sample preparation is carried out by chemical root method. X-ray, K- absorption fine structural measurements were carried out. EXAFS spectra have been recorded at the K-edge of Cu using the dispersive EXAFS (DEXAFS) beam line at 2.5GeV Indus-2 synchrotron radiation source RRCAT, Indore, India. The EXAFS data have been analysed using the computer software Athena. These have been used to determine the bond lengths in these complexes with the help of four different methods, namely, Levy's, Lytle's and Lytle, Sayers and Stern's (LSS) methods.

Keyword: Amino Complex, k-absorption fine structure, x-ray, pyridine-2 carboxamide

I. Introduction

Copper is widely distributed in nature, as metal, in sulphides, arsenide's, chlorides, carbonates etc. Copper is tough, soft and ductile reddish metal. The electronic configuration of these metals is $3d^{10}$ $4s^1$. It has only one electron outside the filled 4d shell. An important physical property of copper is its colour. A transition metal complex consists of a transition metal (such as Cu) coordinated (bounded to) with one or more ligands (neutral or anionic non-metal species). Copper is a moderately active metal. It dissolves in most acids and in alkalis. The present paper describes spectroscopic studies of copper (II) complexes with amino acids as ligands. The amino acid compounds are biologically active, creating considerable interest in their metal complexes [1-4].

The development of EXAFS spectroscopy as a tool to examine short-range inter atomic correlations occurred principally since 1970. The basic physical process leading to the oscillations in the EXAFS region is the backscattering of the ejected photoelectron by the surrounding atoms. EXAFS spectroscopy provides structural information about a sample by way of the analysis of its X-ray absorption spectrum. It allows to determining the chemical environment of a single element in terms of the number and type of its neighbours, inter- atomic distances and structural disorders. This determination is confined to a distance given by the mean free path of the photoelectron in the condensed matter, which is between 5 to $10A^0$ radius form the element [1-4]. EXAFS data can be extracted mainly using two approaches, both of which were first given by Lytle, Sayers and Stern. [5-14] In one method, the Fourier transform of the EXAFS spectra with respect to the photoelectron wave vectors is computed which peaks at distances corresponding to neighbours of the absorbing atom.

II. Experimental: Preparation of complexes

In the present paper, sample preparation is carried out by chemical root method. Pyridine and hydrated copper salt were taken in water, the mixture was refluxed on water bath for 3 hours and left in refrigerator overnight, when the complexes crystallised out. The complexes ware

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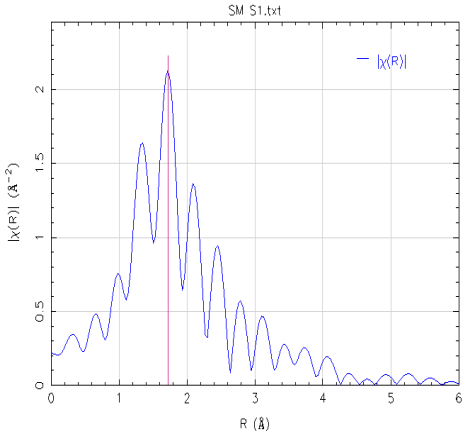
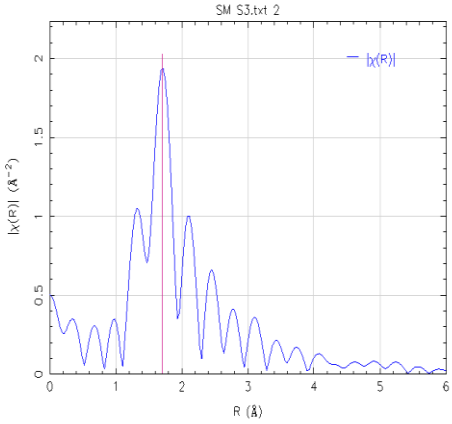
recrystallised and dried in air. This copper salt and amino acids was dissolved in warm water and NaOH added in this mixture. Mixture refluxed for 5 hours on water both and left in water both overnight in a refrigerator when complexes were crystallised it washed with acetone and dried in air. The X-ray absorption spectra have been recorded using synchrotron radiation. The X-ray spectroscopic setup is available at Raja Ramanna Center for Advanced Technology (RRCAT), Indore, India and is called dispersive EXAFS beamline BL-8. This beamline has been recently commissioned at the 2.5 GeV Indus-2 synchrotron radiation sources [2]. Using the relation, $It = I_0e^{-\mu x}$, where μ is the absorption coefficient and x is the thickness of the absorber, the absorption μ (E) corresponding to the photon energy (E) are obtained. The experimental data has been analysed using the available computer software Athena.

III. Results and Discussion

We have determined the bond lengths with the help of Levy's method and graphical methods. We have determined bond lengths using the slope of n Vs k Plots, which gives the value of (R – α) where R is the bond length. The parameter α depends to a large extent on the central absorbing atom. It is found that for chemically similar system, the value of α remains more or less the same. The values obtained for R are given in Table 1. We have also calculated the bond lengths by Levy's method and these are also included in Table 1. It is important to note here that the distance R-α should be equal to the distance found from the L.S.S. graphical method outlined above. Hence, both the L.S.S. method and the Fourier transformation method give the value R-α, i.e., both the methods give the value of bond lengths which have not been corrected for the phase shifts the figure shown in 1.





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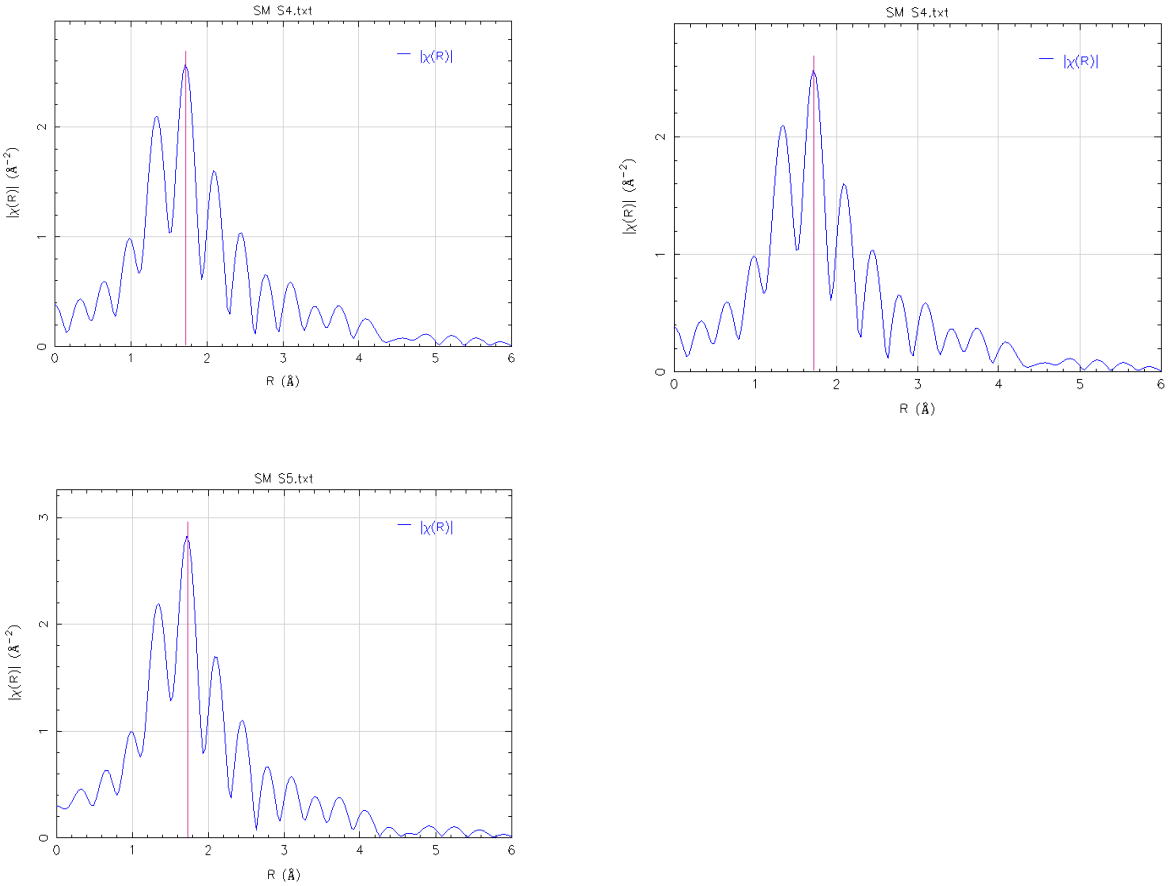

Figure 1 FT for S_1 Cu to S_5 complexes

Table 1 Values of bond lengths calculated from Levy's, Lytle's LSS and F.T methods

S.No.	Complex	Phase corrected		Phase uncorrected	
		Levy's method R_1(Å)	**Lytle's method R_s(Å)**	**L.S.S. method R_1-α_1(Å)**	**F.T. method R (Å)**
S_1	**[Cu (PyC)$_2$Ala] Br.2H$_2$O**	1.86	1.52	1.79	1.71
S_2	**[Cu (PyC)$_2$Ala] Cl.2H$_2$O**	1.80	1.61	1.85	1.70
S_3	**[Cu (PyC)$_2$Ala] (NO$_3$).2H$_2$O**	1.95	1.66	1.86	1.72
S_4	**[Cu (PyC)$_2$Ala] (SO$_4$).2H$_2$O**	1.06	1.86	1.93	1.73
S_5	**[Cu(PyC)$_2$Ala](CH$_3$COO).2H$_2$O**	1.11	1.90	1.94	1.70

IV. Conclusion

From the positions of the EXAFS maxima and minima, the bond lengths in the complexes have been determined by three different methods viz. Levy's, (**1.11Å to 1.95 Å),** Lytle's (**1.52 Å to 1.90Å**) and Lytle, Sayers and Stern's (L.S.S.) (**1.79 to 1.94Å**) methods. The normalized spectra,

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i.e., μ (E) versus E curves have been obtained. From these curves, χ(k) versus k curves have been obtained, which has then been Fourier transformed using the software Athena. From the Fourier transforms (**1.70 to 1.73Å**) of the EXAFS spectra the bond lengths (uncorrected for phase shift) have been determined. It has been observed that the value of the phase uncorrected bond length, i.e., R-α as determined from L.S.S. method and that determined from the Fourier transformation method are in good agreement with each other.

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Evaluation of Recycled Fine and Coarse Building Materials from Demolished Waste

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Abstract: Building construction as well as demolition leads to the generation of unwanted material on site. With the widespread growing constructions, there is increasing demand and interest in aggregates from non-traditional sources such as from industrial by-products and recycled construction and demolition wastes. The goal is on fitness for purpose rather than origin of the resource. The purpose of this research is to review the various sources of aggregate and examine their potential use in concrete and/or road construction materials. Aggregates constitute about 60%-70% per volume of any concrete mixture. Recycled aggregates are useful as an alternative of the natural aggregate if quality is assured. These barriers include higher initial cost, variation in quality, and lack of codes. This experimental study has been considered so that a study on barriers with recycled building materials such as CRCA (Coarse Recycled Concrete Aggregate) and also the FRCA (Fine Recycled Concrete Aggregate) recovered from the concrete waste can be utilized at different percentage levels for making the concrete mixes which can be used as concrete pavers, precast panels, structural elements etc. The concrete mix would be designed for target strength of 20 Mpa and the fresh and hardened properties of mix would be assessed. The experimental studies and investigations would be done to verify the satisfactory performance of the recycled concrete mixes with respect to strength properties. However, concrete has the least environmental avoided impact compared to other building item. In the case of cost estimation for demolished waste, labour and transportation costs were considered.

Key-words: CRCA, FRCA, C&D waste, Recycled aggregates, Concrete mixes, labour & transportation costs.

I. Introduction

One of the important parameters that affect the reuse of recycled aggregate is the variability in the aggregate properties. Quality of the recycled aggregate is influenced by the quality of materials being collected, sorted and delivered to the recycling plants. Therefore, obtaining recycled aggregate at an acceptable price rate and quality is difficult to achieve due the current limitations on the recycling plants. These reasons concern the users about the stability of production and variability in aggregate properties.

The main aim of the current research work is to investigate variability of aggregate properties and their impact on concrete production. Aggregate strength, gradation, absorption, moisture content, specific gravity, shape, and texture are some of the physical and mechanical characteristics that contribute to the strength and durability of concrete. Therefore, it is necessary to evaluate these properties before utilizing the aggregate. In this paper, recycled aggregate from building source are collected from site. In addition, properties of concrete produced with 30%, 60% and 100% recycled aggregates both fine and coarse were investigated. The materials extracted from nature and used in a production process for the first time are referred to as primary materials. Secondary

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materials however, are materials that have been used before and are used again in a new production process. Therefore, replacing primary materials with secondary materials may save natural resources depletion.

II. Problem Formulation

Demolition is the process of tearing down a building to serve the necessary demands. Demolition of buildings and large infrastructures pose significant environmental concerns to property managers and the general public. Typically, demolition activities yield large volumes of waste and if this is poorly planned and managed, enormous volumes of waste end up at the lower steps in the waste hierarch.

Figure 1. Waste end up hierarchy

Reduction of waste has the potential to reduce environmental impact, to improve social welfare and to cut costs related to waste handling. All these ensure the future generation's access to resources is protected. It is therefore imperative to study and develop better construction & demolition waste management schemes, their cost and feasibility evaluation & estimation.

Objectives of the Study

The main objective of the project work is to evaluate the viability of recycling and reuse of demolished building materials with regard to their environmental impact and cost efficiency.
The specific objectives of this study are:

- To establish which materials are suited for reuse or recycle.
- To analyze the amount of recyclable and reusable waste from the demolition.
- Evaluation of the cost of recycled aggregate in comparison of natural aggregate.
- Recommend best demolition practices for the future

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Background

The rapidity of development in the construction industry introduces several concerns regarding availability of natural aggregate resources, as they are being rapidly depleted. Recent statistics showed (Figure 2) the increasing consumption of construction aggregate globally with the highest consumption being in China, America & Asia.

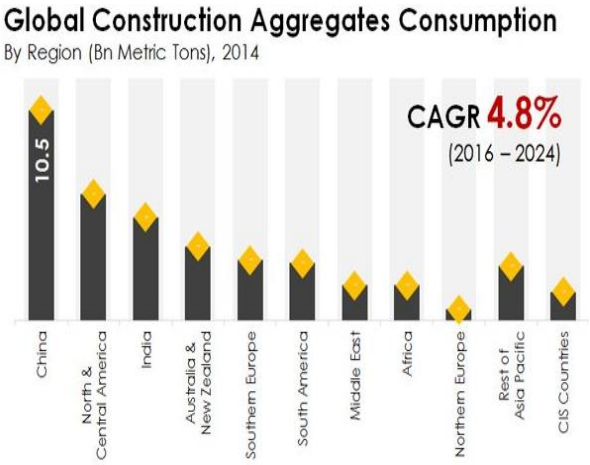

Figure 2. Statistics of consumption

Recycling and Reuse

Recycling today is a solid waste management strategy that is in the same way valuable as both land filling and incineration but more environmentally desirable. Recycling reduces pressure on land which is a big requirement for setting up of landfills. The energy required also for incineration is cut through recycling strategies. In these modern days where resource efficiency has taken root, recycling advancements help to promote the use of secondary materials while preserving the primary resource. Unlike recycling which requires reprocessing in a factory, reuse of material after demolition takes immediate effect and equitable reuse is affected by the method employed during demolition.

Scenario 1 for Environmental Impact - Selective Method

Selective demolition involves deconstructing the building to salvage of re-usable materials as much as possible and recycling the materials that are not profitable to be re-used. This leads to a decrease in land filling which is a waste hierarchy's strategy. The following deconstruction steps in practice for a selective demolition

1. Put out doors & windows frames
2. Remove kitchen fittings, pipe materials, windows and doors
3. Take off floor and wall plaster, wiring and pipes
4. Put down the roof
5. Tear down the walls and floors, story by story

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The building materials that can be re-used in selective demolition as identified h were carefully dismantled without breaking are sold off to retailers. After selective removal of reusable products, this building is demolished and treated in the same way as in the conventional alternative.

Scenario 2 for Environmental Impact – Conventional Method

In this conventional method, use of heavy equipment, hand tools, explosives, etc. are used to bring down the building. At the demolition site mostly without prior disassembly, materials are sorted in different fractions such as wood, steel and inert material for recycling, energy recovery and land filling. In this case demolition energy is needed to bring down the building. Collected materials are sorted and the recyclable materials transported to recycling plant for processing to produce new products (Demolition to Recycling to Use).

III. Literature Review

In [1] Karin Weimann et.al. concluded that there are some high-level applications for a demolition waste and this depends on the crushing processes. This is due to the fact that some important characteristics of crushed concrete sand are different from those of natural sand. His experimental investigation on the treatment of concrete sand gained from demolition waste by wet processing. This gives an idea that if building waste is to be recycled and reused then different method of collecting waste are to be compared.

Hendriks in his research work describes the reuse of construction and demolition waste as aggregates. In addition to the technical quality, the environmental properties of the aggregates were investigated. To meet these limits the demolition process and the upgrading of the out coming waste have to be executed in such a way that the recycled aggregates are not polluted. This leads to an idea that economic and environmental considerations are very important in case of recycled waste [2].

Kurt replaces sand with crushed used (demolished) concrete. The concrete created with this aggregate showed almost the same strength of concrete with natural sand. This is not only much cheaper than river sand and M sand, but also helps to decrease the disposal of construction waste which environmentalists say degrades the land. This is an experimental study to see the feasibility of C&D wastes as fine aggregate in concrete [3].

Md. Safiuddin in his research work investigates about potential use of various solid wastes for producing construction materials. His research work discusses the environmental implications caused by the generation of various solid wastes, and highlights their recycling potentials and possible use for producing construction materials. This leads to an idea that a thorough content of building waste should be the part of the study [4].

Mohan R in his research work observed that river sand is really expensive nowadays as its availability is very limited. So, he replaces sand with crushed used (demolished) concrete. The concrete created with this aggregate showed almost the same strength of concrete with natural sand. This is an experimental study to see the feasibility of C&D wastes as fine aggregate in concrete [5].

Karthik et al in his paper experimentally investigates on the effect of complete replacement of natural aggregate by recycled concrete aggregate in the production of concrete on the compressive

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strength of concrete. Two sets of concrete mixtures of ratios 1:3:6, 1:2:4, 1:1$^1/_2$:3, 1:1:2 by mass were cast using natural aggregates and recycled aggregates concrete respectively. The 28-day compressive strengths of concrete were determined respectively corresponding to 33%, 20%, 11% and 20% reduction in strength compared to concrete using natural aggregate. The densities and compressive strengths of natural aggregate concrete were higher than that of corresponding recycled aggregate concrete. This shows that recycled concrete aggregate can potentially replace completely natural aggregate [6].

In Project Report for MCD, Delhi Solid Waste it is found that C&D waste is a major waste stream, the quantum of which is increasing as a result of increasing construction, maintenance, retrofitting and demolition activities in India. Since the concept of appropriate management of C& D waste is new in this country, information and education is necessary for public support as well as to change the mindset and attitude of all stake holders [7].

Asian Institute of Technology, Report on Reduce, Reuse and Recycle (3R) Practices in Construction and Demolition Waste Management in Asia, begin with the issue there is no proper estimate regarding the quantity of waste occurs in India It focuses on waste management hierarchy which gives an idea to overcome the waste problem [8].

Indian Concrete Institute guidelines on recycling, use and management of C&D wastes, report provides insight into the national and international expertise and experience in the field of C&D waste recycling [9].

Bravo et. al. research analyzes the durability performance of concrete with recycled aggregates from construction and demolition waste. To that effect water absorption by immersion and capillarity, carbonation resistance and chloride ion penetration resistance tests were performed. The analysis of the durability performance shows that it is an influencing factor is by far the RA's composition [10].

Hansen in his study explores the possibility of replacing natural coarse aggregate with recycled concrete construction and demolition waste aggregate for general purpose concrete (i.e. plain concrete and low strength structural concrete). CDW could be transformed into recycled concrete aggregate leading to reduction in the concrete compressive strength ranged from 37% to 62% depending on the type of the CDW constituents [11].

Sachin et.al. in his study determine the structural integrity of concrete blocks. It was concluded that the structural integrity of the CQDB manufactured was not of acceptable quality. This was evident from the compressive strengths attained by the manufactured waste. This leads an idea to study strength and other properties of waste which may prove its usefulness [12].

Fredonia report reports provide the basic properties of recycled fine and coarse aggregates in comparison with natural aggregates. The effects of changes in all aggregate properties like compressive & flexural strength, workability on concrete are discussed with respect to different combination of recycled aggregate with natural aggregate [13].

Parekh et. al compares all aggregate properties and their effects on concreting work. Similarly the

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properties of recycled aggregate concrete were also determined and explained. Basic concrete properties like compressive strength, flexural strength, workability etc are explained here for different combinations of recycled aggregate with natural aggregate. In general, present status of recycled aggregate in India with their future need and its successful utilization were discussed. This leads to an idea that strength and economical like factors simultaneously shall be the part of future study [14].

IV. Result

The following parameters were obtained under the research study

Cost Comparison among methods

Cost Comparison has been made for both methods selective & conventional.

Demolition Cost

Table 1. Demolition cost

Scenarios	Estimated Transport Cost	Estimated Labour Cost	Total Cost (Rs.)
Selective	Neglected for Onsite	6448 Rs.	6448 Rs.
Conventional	Neglected for Onsite	4960 Rs.	4960 Rs.

Labour costs

In this case it was assumed that selective demolition required a total of 5 workers while conventional demolition requires 4 workers. Also, it would require 1h to demolish 4 m2 of floor area conventionally. It was assumed that to do the same job selectively it would require double the time (1hr for 2m2). It would therefore take 20 days considering an 8 hours day Job to demolish 10000 m^2 of building with the conventional method. Selectively it would take 26 days.

Table 2. Labour cost

S No	Scenario	Nos.	Days	Time in hr	Rate/hr	Total
1	Selective	5	26	208	31	6448
2	Conventional	4	20	160	31	4960

Test Result for Fine and Coarse Aggregate

Different test results for Fine and Coarse aggregate are performed and result has been tabulated,

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Test Results of Coarse Aggregate

Name of the Test	Natural Coarse Aggregate	Recycled Coarse Aggregate
Aggregate Crushing Value %	22.77 %	28.1%
Aggregate Impact Value %	33.20%	35%
Water Absorption %	1%	5.1%
Specific Gravity	2.75	2.43

Test Results of Fine Aggregate

Name of the Test	Natural Fine Aggregate	Recycled Fine Aggregate
Silt Content	6%	6.66%
Specific Gravity {gm/cm3}	2.64	2.81
Absorption {%}	.6%	.82%

Test Result for Compressive Strength of Cubes

Compressive strength test has been performed with cubes of 150x150x150mm.

Compressive Strength in (N/mm^2) for M-20 grade of mix (Coarse Aggregate)

Table 3. M-20 grade of mix with 20% coarse aggregate

S No	ID Mark	Slump in mm	With 20% replacement of coarse aggregate		
1.			7 Days	14 Days	28 Days
	CRCA	50	12.1	16.75	18.43

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Table 4. M-20 grade of mix with 40% coarse aggregate

No	ID Mark	Slump in mm	With 40% replacement of coarse aggregate		
2.			7 Days	14 Days	28 Days
	CRCA	50	9.10	12.61	13.87

Table 5. M-20 grade of mix with 100% coarse aggregate

S No	ID Mark	Slump in mm	With 100% replacement of coarse aggregate		
3.			7 Days	14 Days	28 Days
	CRCA	50	6.41	8.84	9.73

Compressive Strength in (N/mm^2) for M-20 grade of mix (Fine Aggregate)

Table 6. M-20 grade of mix with 20% fine aggregate

S No	ID Mark	Slump in mm	With 20% replacement of fine aggregate		
1.			7 Days	14 Days	28 Days
	FRCA	50	13.21	17.45	21.1

Table 7. M-20 grade of mix with 40% fine aggregate

S No	ID Mark	Slump in mm	With 40% replacement of fine aggregate		
2.			7 Days	14 Days	28 Days
	FRCA	50	7.32	10.86	12.67

Table 8. M-20 grade of mix with 100% fine aggregate

S No	ID Mark	Slump in mm	With 100% replacement of fine aggregate		
3.			28 Days	7 Days	14 Days
	RCA	50	12.67	6.67	7.31

V. Discussions

Cost estimation analysis shows that the selective demolition costs twice more than conventional demolition. However, revenue from selling off reusable material from demolition was not considered in our study which could compensate for some of the demolition expenses. It is hard to conclude that moving to higher steps in the waste hierarchy is more environmentally friendly since land filling and energy recovery which fall in the lower stages of the waste hierarchy are not

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considered in this study. However, reusing material has less environmental impact than recycling due to the cutoff of transportation and energy consumption in the recycling plant. Age and type of building has an effect on selecting the demolition plan. In case that building is in its end of functional life where deconstructed material cannot be reused after applying various types of demolition equipment, then maybe conventional plan is a better choice. The strength of concrete by replacing coarse aggregate instead of fine aggregates provides higher strength to the mix. Also, strength of concrete by replacing a particular percentage say about 20% yields more strength almost double then that of replacing by 60% 0r 100%. Also 100% replacement of aggregate doesn't provide a remarkable strength. The slump value is found to be around 50mm which shows that concrete with recycled waste would be suitable for work of porous importance.

VI. Conclusions

Selective demolition seems to be more environmentally friendly than conventional one. Selective demolition is costly due to the reason that building materials are carefully dismantled. There is less environmental impact of selective demolition than recycling due to categorization of items and the cut-off of transportation & energy consumption in the recycling plant. Conventional plans are more symmetrical and used to in practical approach & hence are a better choice. The strength of concrete by replacing coarse aggregate or fine aggregates yields a lower strength ratio due to the reason that aggregates properties doesn't remain in the natural state. But using special admixtures or fibre material strength may be achieved. The slump value is suitable for work of porous importance or colony road work.

Acknowledgements

Authors are grateful to Er. Ashok Sojatia, Chairman (BOG), AITR & entire management authorities for giving motivation at various stages of this project. Thanks, are expressed to Dr.SK. Sohani, and Dr. SK Sharma, HOD Civil Engineering, AITR for his valuable suggestions & critical comments at various stages. Thanks, are also expressed to Mr. Sharad Naik & staff for key guidance about testing parameters. And, at last but not least to all those & my late parents were always behind me to encourage for pursuing study and made all sort of sacrifices during research work at AITR, Indore.

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Manufacturing Fly Ash Brick by Using Plastic Waste and Bitumen

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Abstract: India is suffering from huge problem of solid waste management in this age of rapid development and the major portion of this solid waste comprise of polyethylene, especially LDPE. Plastic waste has become one of the major environmental problems, so by utilizing plastic in a useful way we can reduce the burden on environment by a huge margin. In this study, an attempt has been made by replacing the cement used in the fly ash bricks by low density plastic as the binding material. By using plastic as a binding material rather than cement, it can be proved beneficial to the environment in multiple ways. Hence, in this study LDPE waste is used for making fly ash brick using molten plastic (instead of cement) and bitumen. Different mixes of Fly ash: Plastic: Bitumen (F: P: B) ratio are prepared and then tested. The composition of different materials being tested are: i). 60% fly ash, 35% molten plastic and 5% bitumen by volume and ii). 60% fly ash, 38% molten plastic and 2% bitumen by volume. The results will then be compared with that of conventional bricks (i.e. clay bricks and fly ash bricks) on grounds of compressive strength, water absorption as well as on the basis of economy (approximate cost per brick). The results found were compatible and hence it could be suggested that plastic waste could be used for the making of fly ash bricks.

Key-words: Fly ash bricks, Waste Material, LDPE, Bitumen.

I. Introduction

Plastic waste had become one of the major environmental problems, so by utilizing plastic in a useful way could reduce the burden on environment by using plastic as a binding material rather than cement can be proved beneficial to the environment in multiple ways:

- Cement industry is the largest energy consuming industry in the world.
- By reducing use of cement could reduce the carbon emission from cement industries.
- Plastic poses many environmental problems which can be avoided.
- It solves the increasing problem of dumping of polyethylene in dumping grounds.

In this study fly ash bricks were made using molten plastic waste (LDPE) and bitumen mix. Different mixes of different Fly ash: Plastic: Bitumen ratio will be prepared and then tested. The results will then be compared with that of conventional bricks.

Low density polyethylene (LDPE) is an important industrial material because it is durable, light-weight, easily processed and characteristically inert, but its everyday use is hazardous to the environment, plastics are a rapidly growing segment of the Municipal Solid Waste (MSW) stream. The dumping grounds in cities like Indore, Mumbai, Delhi etc. have become a major environmental threat and health hazard for the people living nearby. The Deonar dumping ground fire tragedy is well known for its huge adverse impact on environment and health of people of

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Mumbai. In a country like India where the population is going to cross 1.4 Billion in coming years the solid waste management is going to be a much more difficult task.

According to a new Ellen MacArthur Foundation report launched at the World Economic Forum, new plastics will consume 20% of all oil production within 35 years, up from an estimated 5% today. Plastics production has increased twentyfold since 1964, reaching 311m tones in 2014, the report says. It is expected to double again in the next 20 years and almost quadruple by 2050. Despite the growing demand, just 5% of plastics are recycled effectively, while 40% end up in landfill and a third in fragile ecosystems such as the world's oceans. Under these circumstances the recycling of plastic waste has become very crucial. Plastic take millions of years to decompose and hence the only way left through which it can be re-utilized is by innovating new methods to recycle it.

Properties of LPDE

PE is classified as a "thermoplastic" (as opposed to "thermoset"), and the name has to do with the way the plastic responds to heat. Thermoplastic materials become liquid at their melting point (110-130 degrees Celsius in the case of LDPE and HDPE respectively) [2]. A major useful attribute about thermoplastics is that they can be heated to their melting point, cooled, and reheated again without significant degradation [3]. Instead of burning, thermoplastics like Polyethylene liquefy, which allows them to be easily [injection moulded] and then subsequently recycled.

By contrast, thermoset plastics can only be heated once (typically during the injection moulding process). The first heating causes thermoset materials to set (similar to a 2-part epoxy) resulting in a chemical change that cannot be reversed. If you tried to heat a thermoset plastic to a high temperature a second time it would simply burn [6]. This characteristic makes thermoset materials poor candidates for recycling.

Unique Properties of LDPE

- The melting point for average, commercial, low-density polyethylene is typically 105 to 115 °C (221 to 239 °F)
- Absorbs almost no water. Density range of 0.910–0.940 g/cm3. [3]
- Has good binding properties thus can bind fly ash particles effectively.[5]
- It is non-reactive at room temperatures. Polyethylene is a homo-polymer in that it is composed of a single constituent (in this case ethylene: CH2=CH2).[1]

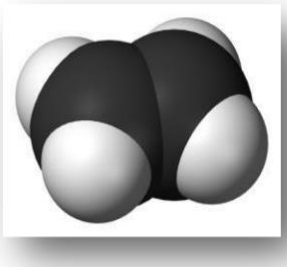

Figure 1. Ethylene (CH2=CH2)

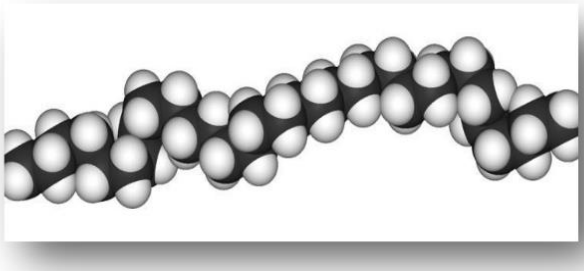

Figure 2. Space fill model of polyethylene

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Materials Used

Mainly three materials have been used in making these bricks namely Fly ash, LDPE and Bitumen. The properties of Fly ash, LDPE and bitumen are given below in tables. [2] Type of plastic used: Low Density Polyethylene (LDPE)

Table 1: Properties of LDPE

Chemical formula	(C2H4) n
Density	0.91-0.94 g/cm^3
Melting point	115–135 °C (239–275 °F)

Type of fly ash used: Ash produced in small dark flecks by the burning of powdered [4].

Table 2: Properties of Fly ash

Density	1.06 g/cm^3
Specific gravity	2.1- 3.0

Type of bitumen used: It is a semi-solid hydrocarbon product produced by removing the lighter fractions from heavy crude oil during the refining process [5].

Table 3: Properties of Bitumen

Density	1.06 kg/m^3
Melting Point	110-120^{o}C (240^{o}F)

II. Review of Literature

According to Singhal et al plastic waste is a non-biodegradable waste that cannot decompose and this creates water, land pollution, and air pollution. Also, while burning the plastic waste in dumping ground, the percentage of plastic waste was increasing rapidly. It was estimated that plastic waste will double after a decade as it has been observed that hundreds of grades of plastic used in our daily life. now, recycle, reuse the plastic waste is our need [7]. As a civil engineer, innovate something new related to this is must be needed, which was a boon for civil engineering. So, here took trial to do something innovative as plastic sand bricks/ tiles. Basically, in bricks and tiles, conventionally use of earth-based clay. Due to excessively used of the clay, it shows the result of resource depletion and environmental degradation. In plastic waste, for experimental considered drinking water bottles (polyethylene terephthalate), carried bags, bottles caps, house held articles (high density polyethylene), milk pouches, sacks, carried bags, bin linings, cosmetics and detergent bottles (low density polyethylene), bottle caps and closures, wrappers of detergents, biscuit (poly propylene), electrical fittings, handles and knobs (urea formaldehyde), casting, bonding fibers (polyester resin) etc. In this, need to crush the plastic waste into fine particles and heated on a furnace (bhatti). and also used stone dust as fine aggregates (size below than 4. 75mm), heated on a furnace (bhatti). Now, then put mix heated plastic waste and heated stone dust and

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poured into mould and form bricks and tiles. after above process it would be observed that the characteristics of bricks and tiles was far much better than normal bricks and tiles as minimum water absorption, highly compressive strength, smoothed surface, unbreakable, less weight etc.

II. Methodology

Making bricks with different Fly Ash-Plastic-Bitumen(F-P-B) composition: -

- 50% - 45% -5%
- 50% - 48% - 2%

The waste plastic is collected from Dump area and then weighed depending on the number of bricks to be made out of it. For example: 1 brick of 50% - 45% -5% F-P-B composition needs 1.14 Kilograms of Fly-Ash, 0.66 Kilograms of plastic and 0.95 Kilograms of bitumen.[4]

Figure 3. Plastic being melted in container

Figure 4. Molten plastic slurry

Figure 5. Fly ash being mixed in melted plastic

Figure 6. Mix placed in mould compacted and bitumen

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Figure 7. Brick after removal from mould

Testing

The bricks are ready to be tested after 24 hrs of casting, in 24 hours the bricks gradually get cool down and thus the plastic gets hardened. Compression test and Water Absorption test are performed for analysis.

Calculations

Compression Test Results

- Average compressive strength of 60% - 35% - 5% (F-P-B) bricks = 92 kg/cm2
- Average compressive strength of 60% - 38% - 2% (F-P-B) bricks = 90 kg/cm2

Water Absorption Test

- 60% - 35% - 5% (F-P-B) bricks: Water absorption of this brick = 5%
- 60% - 38% - 2% (F-P-B) bricks: Water absorption of this brick = 6%

III. Results

Table 3: Comparison of Conventional and F-P-B bricks for various parameters

Block type	Composition	Brick no.	Weight of Brick (Kg)	Average wt. of the Brick (Kg)	Strength Kg/cm^2	Average Strength Kg/cm^2
		1	3.52		32.71	
		2	3.48		32.52	
Clay Bricks	-	3	3.49	**3.50**	34.34	**33.27**
		4	3.51		31.56	

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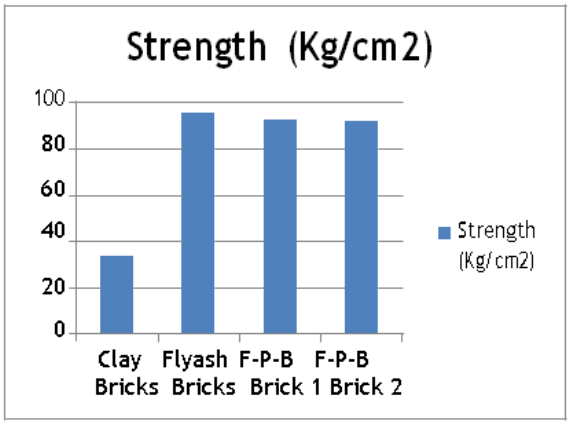
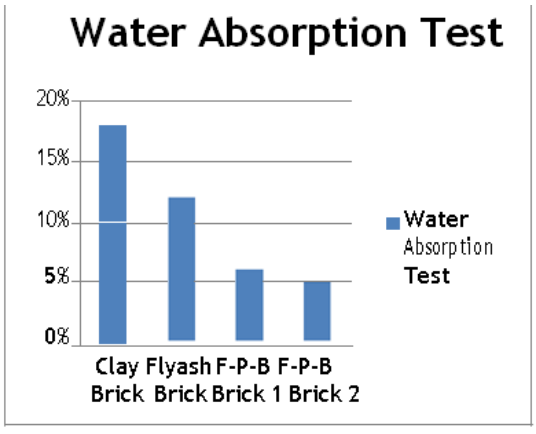
		5	3.50		35.23	
		1	2.60	**2.60**	94.36	**95.15**
		2	2.58		94.24	
Fly ash bricks	-	3	2.62		98.32	
		4	2.59		93.28	
		5	2.61		95.58	
		1	1.92	**1.90**	94.42	**92.51**
		2	1.90		88.32	
F-P-B Brick$_1$	60% -35% -5%	3	1.89		93.26	
		4	1.91		92.27	
		5	1.88		94.30	
		1	1.90	**1.90**	89.23	**90.48**
		2	1.91		92.85	
F-P-B Brick$_2$	60%-38% -2%	3	1.88		90.64	
		4	1.92		91.38	
		5	1.89		88.32	

Table 4: Water Absorption Table

Type of Brick	**Water Absorption**
Clay	18%
Flyash	12%
F-P-B Brick$_1$ (60% -35% -5%)	5%
F-P-B Brick$_2$ (60%-38% -2%)	6%



Graph 1: Strength of Bricks.



Graph 2: Water Absorption (%) of Bricks

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Cost Analyasis

Type of Brick	Cost (INR)
Clay brick	5 - 5.50
Fly ash brick	3.50 - 4.00
F-P-B brick1	3 – 3.50
F-P-B brick2	2.50 - 3.00

IV. Conclusions

From the strength table it is clear that the strength of F-P-B bricks of both proportions is almost same as the strength of conventional bricks. But as far as other properties are concerned namely water absorption and brittleness, the F-P-B brick is proved to be better than conventional bricks. The water absorption of F-P-B brick is drastically lower than that of conventional bricks, which implies that the material can also be used as water resistant covering on roof top. The weight of both F-P-B brick is less than that of conventional bricks as the density of LDPE is less than that of Cement. Though the strength F-P-B brick is less than that of conventional fly ash brick, the one quality that was observed was that the F-P-B brick is less brittle than conventional bricks the reason being that the plastic is used instead of cement which has a tendency to get deformed under application of load. F-P-B bricks have very low water absorption as compared to conventional bricks reason being that the plastic does not absorbs water. This gives the block a unique property of water resistance which is absent in conventional brick. F-P-B brick can be used in all weather conditions. No curing is required in making of F-P-B bricks as plastic doesn't require water to gain strength; it naturally gains strength when gets cool down. Cost to Benefit ratio of F-P-B brick is more than that of conventional bricks.

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